Display Ecologies Workshop Report

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Introduction

The first section of this report covers the initial framing of the workshop that rook place. The second section discusses some of the topics that came up over the course of the workshop, which were seen mostly as overarching / generalised concerns regarding display ecologies. The final section explores some details regarding what each speaker discussed, and the issues they brought up. This report is obviously the product of many participants, and as such any errors are only introduced by my writeup.

There were three main aims of the workshop:

1) To review existing interaction techniques, examples of existing situated display and display ecology work (including any existing taxonomies, software infrastructures, etc.). Compare and contrast existing work in Horizon on display ecologies, and draw on experiences of external attendees working in this space.

2) To determine what research questions – design, conceptual or infrastructural – need to be answered.

3) To determine whether there is scope innovation in the display ecologies space (e.g., develop new infrastructure, conceptual work).

Framing display ecologies

The main purpose of the workshop was to explore public interactive display ecologies – often called 'situated displays'. Notions of 'situated displays', however, are not wide enough a concept to capture the diversity of configurations and forms of physical display (as well as social aspects of 'display' and 'displaying') that we both encounter in the literature as well as located within the content of the workshop. Instead, it seems that an 'ecology' metaphor affords us greater purchase in understanding the design space.

Ecology evokes a range of useful concepts, such as how ecologies are composed of hybrid elements, their heterogeneity in that they fit together or are made to fit together and yet retain boundaries and seams. Overall, ecology as a metaphor is invoked to suggest the 'messy' reality of real-world configurations of display. 'Ecology' also implies display systems that exist in an ever-changing environment. It implies that these messy interrelated components might self-organise in some way. Ecology implies things might be brought into play that we didn't expect - new objects and so on which might interact with the displays somehow but we didn't expect them to. Ecology implies display elements that mesh more with non-digital resources and a wider understanding of what a 'display' is or might be.

Display ecologies have been on the research agenda for a long time, particularly within ubiquitous computing, in that very early on researchers were concerned with the production of a large number of display prototypes that fulfilled various functions (computing by the inch, foot and yard). Extensive studies have already been conducted in many environments with complex display ecologies, particularly relevant is well-known CSCW research on workplaces, control rooms and media spaces, such as Gaver et al. (1993). These studies have explored collaboration and coordination with and around displays ecologies (e.g., London Underground), couplings or interlinks between displays and artefacts (e.g., Air Traffic Control), mutual monitoring, issues of awareness and the physical arrangements of these displays.

So when we are coming to think about display ecologies, and how to develop and study them, we must remember these precedents. Further to this, more recently we see increasingly that ecologies are now 'out there' in a wide range of public settings. Indeed, as well as existing research projects (e.g., e-Campus networked public display system), we see increasing precedents in commercial systems, such as emerging networked digital signage (e.g., CODA).

What are display ecologies?
There is the initial problem of the application of the metaphor meaning that everything being included in a display ecology. Instead we should see this just as meaning that the design boundaries are fuzzier than situated displays.

Display ecologies encompass ranges of scales, digital features, and a range of interactivities, a range of coupling techniques. Typically these 'display ecologies' are arrangements of *interactive* and *non-interactive* displays, interlinked in some way, situated in *public or semi-public settings*, such as urban environments like train stations and airports, the sides of buildings, or town squares, or perhaps cultural locations or sporting places such as museums or stadiums. These settings obviously change as part of becoming embroiled in an ecology.

Components of these display ecologies may range in *scale* from micro-displays, small 'tiles' or handheld displays to video-walls or even building-size projections. Also with scale we get *spatially distributed* display ecologies.

Display ecologies are often 'hybrid', i.e., they may be assemblies of mixed display *types*, such as display tiles (e.g., Sifteo cubes), pico projections, mobile phones, laptops, wall projections, interactive whiteboards, large information

screens (e.g., displays in train stations), or clusters of monitors. Displays may be a device itself or *projected* by a device (e.g., onto walls, or even onto people).

In our workshop, we extensively considered *non-digital* components of display ecologies, such as paper, standard whiteboards, etc. Displays within these ecosystems may range between being fixed or mobile. Being hybrid, they can also have *mixed forms of input*, e.g., touch-based, computer vision-based (e.g., gestural), traditional mouse and keyboard, or no direct input capabilities. Further, displays may have quite different physical affordances, such as flexible paper displays versus cube-like solid tablet displays.

Display ecologies may also involve other, more spatially distributed interactive displays spread across multiple settings. Couplings between components of an ecology is a further crucial aspect, e.g., interaction between large displays and mobile phones. Components in display ecologies also may have a range of *mobilities*, thus they may be fixed displays (e.g., information boards), mobile displays (a phone) or perhaps displays that are restricted to a particular space or path (e.g., museum guides).

The hybridity, heterogeneity and distributed potential of display ecologies composed of assemblies of mixed display types, and non-digital components, leads us to question how it is that these things fit or mesh together.

In an attempt to summarise these issues collectively, display ecologies cover a range of situations and settings, with design dimensions of flashpoints often being:

- The role of participants – with and without access to display technology.
- Synchronicity – whether they support synchronous or asynchronous participation.
- The distribution of displays
- The componentisation and number of displays.
- The form and type of displays – digital or non-digital, paper or flat screen.
- Interaction models that allow access to the display or displays (e.g., broadcast models versus one-to-one participation techniques). How these models fit with the nature of coordination and collaboration in the space of participation.
- Coupling strategies between displays.
- The role of unexpected devices, display ecology adaptation and evolution over time.

Taxonomies and frameworks
There are a couple of obvious divisions between frameworks and taxonomies in the display ecologies space. The first type is frameworks about the structure of interactions with and around display ecologies. For instance, work has been done structuring different zones of interactions around situated displays, as found in Brignull & Rogers (2003) paper on zones of interaction. Zone (a) is 'peripheral awareness' where people are peripherally aware of the display only, and so may be unwitting to some extent of their interactions with it. Zone (b) is where focal awareness takes place, with

activities associated with the display by people. Zone (c) involves direct interaction with the display (via a laptop).

Another example of this is from Müller et al. (2010)'s framework of the 'audience funnel', which structures the space in a bit more detail, and includes notions of participation and collaboration around the display with multiple users. These frameworks map some kind of trajectory / approach / disengagement etc. from displays.
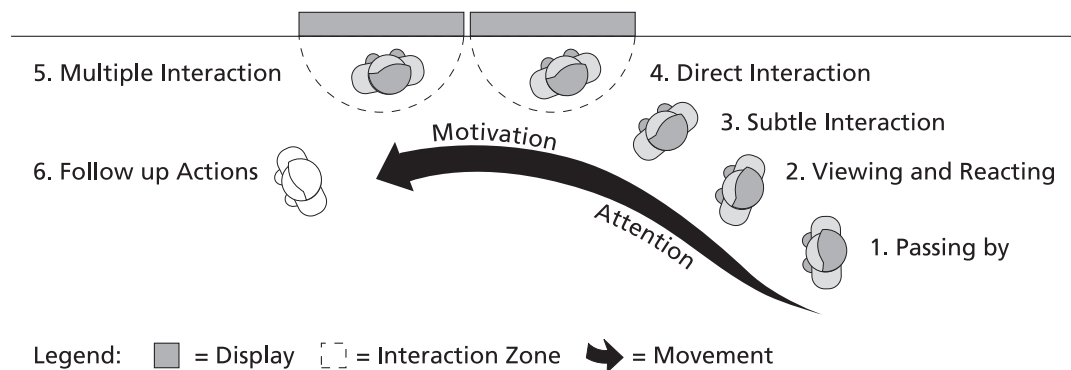
Figure 1: The Audience Funnel (adapted from [39])

The second type of work in this area is taxonomies of display ecologies themselves, typically involving categorisations of the different types and forms of display ecologies.

Müller et al. (2010) is based on ranges of implicit or explicit forms of interaction – detecting presence versus touching a display, different interaction models, e.g., a poster format, display mirroring, a window metaphor (below).

Mental Models / Interaction Modalities	Poster	Windows	Mirror	Overlay
Presence	Hello.Wall, BluScreen		Palimpsest, Videoplace, Vision Kiosk	
Body position	Cylindrical Screens			
Body posture				Jumping Frog
Facial Expression		Hole-in-Space	eMir	
Gaze	ReflectiveSigns			
Speech				
Gestures	Interactive ambient public display, Pendle		Magical Mirrors	Diaper Selector, Traveling TicTac-Toe
Remote Control	Touch Projector			
Keys	Opinionizer			
Touch	CityWall	ShadowBoxing		

(implicit → explicit, shown along the left vertical axis)

Table 1: Taxonomy for Public Displays

Terrenghi et al. (2010) identify three main aspects of situated displays: scale, social formations with / around displays, couplings. The different dimensions are elaborated as follows:

1. Scale of displays: inch, foot, yard, perch, chain;
2. Social interaction forms: one-to-one, one-to-few, few-to-few, one-to-many, many-to-many;
3. Coupling / binding methods for inter-display interactions:
   a. synchronous human movement (e.g., synchronised movement of displays),
   b. continuous action (manipulating content across displays),
   c. action and infrastructure (pre-configuration of displays)
4. Combinations of the above dimensions

(Below.)

Table 4 The relation between the attributes of multi-person-display ecosystems

Social Interaction	Scale				
	Inch	Foot	Yard	Perch	Chain
One–one	GenyTM	Bumping and stitching	(Allows privacy) UbiTable		
One–few			Pick and drop		
Few–few		Proximity Regions, Savannah	Dynamo	+i-Land	
One–many					Blinkenlights
					Regrets
Many–many				Tune_eile	UniVote

Table 6 Relationship between social interaction support and multi-person-display ecosystem scale

Concepts

Some of the concepts that were picked up on during discussion sessions:

- Seemed to be a theme of employing display ecologies for the purposes of persuasive technology, and presumptions of use in assisting behaviour change. How displays shape behaviour or can be designed to.
- Another common theme of energy projects, which seem important as part of display ecologies work we are all involved in.
- We discussed consumption of content from display ecologies versus 'push back', i.e., addressing the spectator / participant themselves rather than just broadcast only.
- 'Beyond display ecologies' – we attempted to address the messy reality and characteristics of display ecologies – display ecologies that exist already. Beyond display ecologies in the sense of also thinking beyond the point when display ecologies are a defined 'thing'.
- Issues of adaption and integration – adding to existing display ecologies, and how hard this might be. A bit issue seems to be the changing of display ecologies over time.
- Viewpoints presented by or inherent in display ecology design and configuration – where you see the displays and how you get to interact with them – displays embed particular views – who is the viewer?
- Display ecology aethestics versus functionality. The role of narrative, ambiguity, etc. in interactions with them.

- A common theme of display as a verb (e.g., an act of display), rather than as a noun (e.g., a display). This seems crucial when coming to think about what display ecologies are.
- Very large infrastructure challenges associated with display ecologies: issues of specific versus generic systems, and what level infrastructures can aim at, challenges of developing infrastructures that may adapt over time, infrastructures that may deal with unexpected interactions, or the introduction of new, unaccounted for devices.
- A relationships challenge – how display ecologies fit into existing human ecologies.
- What are appropriate benchmarks for display ecologies?
- Content appeared to be often quite secondary to our discussions. Content is crucial, however, and what the content is may determine what display ecologies look like.
- What do display ecology editors and toolkits look like?

Presentations

This section briefly details some relevant points for display ecologies work that each of the speakers discussed.

Yvonne Rogers

Discussed separating out displays as opposed to employing one large individual display, fostering collaboration side-by-side and supporting an increased ability for crowding around flat, multi-linked displays (as opposed to a single display). Display ecologies might involve deliberate 'fractures' in order to support collaboration.

Large groups engaged with display ecologies (e.g., 30 people plus), using a small displays (iPads) and a shared large display linked to them (with a publish-to-large-display model). Moving away from direct interaction with a large fixed display to multiple smaller displays that are coupled with the large display.

Awareness and display ecologies – aggregate awareness at 'street level' rather than individual awareness. Physical public displays such as chalk 'plotted' on the tarmac of a street.

Matt Jones

Can display ecologies be broken down and stored, and then reassembled?

Display ecologies evolve, have a variety of species, they accommodate, and they engage.

Display ecologies need an appropriate canvas that is big enough so that no-one can be completely in control and yet small enough to encourage participation.

Display ecologies don't give all the answers but can encourage exploration, open question rather than pretend to provide answers. Ambiguity.

Gave the example of a display with seating; we don't often see displays with seating (especially seating facing the 'wrong' way, but enabling someone to be seen in front of the display).

Further example of juxtaposition of displays – certain kinds of spaces encourage growth of displays.

Paper can be an important element of a display ecology.

Display ecologies must be able to support 'mashed-up', uncoordinated, competing or collaborative displays. What kind of digital infrastructure is needed to support this? What physical materials are needed to support this? E-ink? E-paper?

Participants required to say "I want a turn" maybe means that there is something wrong with the display ecology.

Display ecologies involve "space as display" – also reflected in Tom Rodden's talk.

Tom Rodden

The ecology of physical setting in which technology gets placed. These spaces are adapted and changed greatly over time. What's the display ecology's flexibility and availability to change?

Rethinking 'display' as a verb as well as a noun – i.e., the act of display, places of display, and whereabouts display takes place. For instance, display surfaces – places that are employed for the act of display – e.g., putting a letter in a particular place so that it may be seen by others in the house.

Homes as ecological habitats – places where 'stuff' clusters, where activity centres of where stuff is dealt with emerge.

Display ecologies as a next generation of distributed windowing systems. The foundational presumptions embedded in windowing environments, and questions of what happens when we change those?

Display ecologies involves a task of redesigning underlying event models to support what a display ecology is and can do. E.g., the Dynamo system, which rethinks the display server concept by carving off portions of the display for access control.

Steve Benford

Day of the Figurines – table, figurines, projection system, small screen at the end of the large table.

Display ecologies that feature in Blast Theory's Day of the Figurines work. Blast Theory designed the lighting to create the right visual impact on approach to the table that provided the 'game board' for the figurines; it also was created with a distinct front and back. Designed to encourage visible physical interaction with table (bending over), and promote physical engagement with figurines – bonding with the object that links the disparate elements of the experience across media (SMS, web, physical installation).

Interesting aspect for thinking about display ecologies is the asymmetry of the 'display' table.

Another Blast Theory work, Flypad, which employs multiple different views using a complex display ecology involving terminal screens and large displays. The display ecology in Flypad was a response to a specific building space – the specificity of the ecology for the space.

Theme parks as a complex ecology of different display devices. There are design tensions between systems provided by the park and visitor's own technology (e.g., on-ride capture systems versus own digital camera use). Visiting in groups – people wanting to support own personal stories, conflicts between members of the group.

Automics knits together different photo resources around the theme park – display ecologies could reflect on this kitting together of varied resources.

Holger Schnadelbach

Discussed Mixed Reality Architecture – a video conferencing-like system that connects offices. Introduces the importance of the visibility of things in the display ecology of the MRA that are made available in the video streams – e.g., whiteboards, other people, bits of other architecture.

MRA creates a hybrid spatial topology alongside existing physical (and more fixed) topologies of buildings. This flexible topology meshes with the physical topology, and distorts / changes what people can see in physical space. Display ecologies can be part of such hybrid linked spaces.

Boriana Koleva

Upcoming CHESS project: using personal mobile phones as guide through visit – an ecology of different interfaces that mobile phones integrate with. In one museum (a space museum) there are pre-existing interfaces. There is a need to think about how to link into the existing display ecology that features in the museum.

Strong theme seems to be the introduction of new parts to existing display ecologies – but what kind of reality are we going to create? Not the Microsoft Windows of display ecologies infrastructures – plug and pray, etc.?

Joel Fischer

Energy awareness projects (ORCHID) using agents to report back to users. Software agents may need to curate information which is then displayed back to the user.

Display ecology governed by agents. Challenge of integrating a variety of different views / displays / interfaces in the home, again meaning that we encounter the challenge of displays being added to an existing ecology of the home.

Home display ecologies spaces – two dimensions of private versus public, control versus monitoring interfaces. Challenge of how the display elements fit together.

Understanding the existing ecology in the home, as well as the existing display ecologies. A whole family of displays might be 'overkill', and instead

use different display ecologies for different communities. Raises issue of understandability of the data – who is the display for?

James Colley

Display ecologies for personal energy monitoring (James' PhD work). Moving from individual situated displays for energy monitoring to interlinked ecologies of displays. Combining them can be more informative.

Question of whether interlinks between display components are a signature of display ecologies – is that what display ecologies are?

There is a difference between display of energy compared with having to do something to understand that energy use. Disconnection between effort and results of that effort (e.g., maybe display here is not useful).

The ecology needs to include the devices that are requiring the energy (e.g., point of information is the kettle – which is the point of action as well). Do you need immediate feedback from the display? How much constant feedback do you need or even predictive feedback?

Display ecologies for energy monitoring have 'anchor points' – i.e., places where energy is consumed rather than the people who consume it.

Display ecologies need to support unpicking of energy use. So, going from the 'top level' – the electricity that is used, and tracing this back to the 'bottom level', i.e., the device that is consuming the power.

Rob Houghton

Car sharing projects (within Horizon) employing display ecologies via two groups of displays – a big situated display and mobile phone display via text. Having the display in a public space 'normalises' car sharing.

Interest in display ecologies for emergency services, military and NGOs. E.g., inquiry into London bombings, emergency services having problems with interoperability.

Display ecologies are used (or should be used) to deliver a common operational picture. Display ecologies need to be able to separate slow information and fast information out.

Display ecologies need to be built, but then offer the capability of being taken apart again.

The power of the paper culture in operational environments. People who print out emails and 'call them memos'. How to reconcile this with digital components of display ecologies?

Display ecology components can be far too rich informationally to be practically useful.

Where do issues with display ecologies reside? Is it a problem that can be solved with better displays? Is it a social problem? Or do we just need better data?

Rachel Jacobs

Display ecologies example of private experience of playing games on your phone and how that interacts with very big public screens (Heartlands). Different types of interactions / different visualisations were chosen for different spaces. Used flyers as maps to the game.

Exploding Places used similar format for the display ecology, i.e., a very personal game screen which the player used, and a large screen as a way of inviting people along to the event. This enabled visibility for being able to see the game evolve over time (like Day of the Figurines' table). Issues of legibility were present, such as problems with narrative (e.g., not understanding what was going on the screen).

These display ecologies were about revealing interaction through a display. There was a relationship between physical movement of participants and the large interactive display. Tricking people into thinking they were controlling more things than they actually were – deception in a display ecology.

A Conversation Between Trees involves sensor data visualisations that are burned as rings into paper. There is a live visualisation of this data on participants' phones, as well as large screens in an exhibition space with visualisation of sensor data from trees in Brazil and UK. Adapting mobile phone view of the forest with real-time data live from the forest. Dialogue between two sets of data – how it 'feels' rather than what the raw values are. Display ecology includes a van with projections, laptop screen visualisations etc.

Abigail Durrant

Examined negotiations over the content of shared photographic displays – of control and of content that is put on them. Shared access tools.

Designing display ecologies that constrain negotiations between participants and foster positive interpersonal communication and understanding.

The role of photos in the home – exploring how family photos are represented in the home and how technology of display ecologies can work in the home to support this.

Display ecologies and the importance of curation (curation of home displays). Studied how teenagers managed the display of media they generated in the home. This work challenges assumptions about what defines public / private spaces. How one might design display ecologies for subtle expressions as found in the home. Notions of 'display' introduces physical / digital constraints on what can be seen when.

Theme park souvenirs and how media (photos etc.) might be consumed in situ at the theme park. Framing of different interests in sharing resources on a display – explicitly explore design through relationships of people and the content they are accessing through this.

Foregrounding design in display ecologies for conflict type situations?

James She

Discussed interactive displays for advertising / smart signage. Distribution of display data via low-tech transport means (e.g., USB stick in a truck).

Display ecologies can draw from existing principles of effective advertising (via traditional means):

- Decisions made based on advertising goals, what they want to communicate and focus (increased sales etc.);
- Message strategy (e.g., emotional means, endorsement, etc.);
- Message distribution (e.g., repetition, selective exposure, etc.).

Stages of user experience for advertising displays:

- Attention catching
- Interaction – understanding the message
- Conation – take-away potential, word-of-mouth etc.

Use of mobile phones as auxiliary device for display ecologies. Display ecologies can trade on familiarity – no new interfaces to use, permits personal / private interaction, storage space, human mobility networks and mobile conations.

Using human mobility networks rather than broadcasting – the role of people in display ecologies as themselves methods of display.

In projects has found that interaction between participants and displays can lead to pairings that are too complex; instead display ecologies can pursue other means for interaction, e.g., passive strategies like vision-based techniques. Importance of adjusting content as appropriate to user.

Scalability is an issue for smart signage, and multi-signage interaction is really hard.

These signage systems have used QR codes to support interaction, and scalability. Easier that other systems such as Bluetooth, bespoke computer vision solutions etc.

Display ecologies that used broadcast as a communication channel rather than one-to-one. (Communications presumably that are ok for broadcast to everyone.)

Methods for interacting with displays – they have developed techniques for 'dragging' information off a display, using a gesture over wifi multicast, which scales to many people. This about working out ways to do coupling. Separation between the display content and content 'dragged' off.

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