Towards a pattern language for describing ubiquitous interactions

Kõikjaleulatuvaid interaktsioone kirjeldav mustrikeel

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Summary

Building upon previous, extensive literature review on distributed user interfaces, this paper traces the attempt to collect all instances of interaction techniques targeted towards Multi-Display Environments into design patterns, general reusable solutions to problems unique to the area of MDEs. Once these problems are properly identified and their solutions collected into a pattern catalogue, the study expands into applying taxonomic and social network analysis to identify how these solutions relate between themselves and build the scaffolding for a pattern language on distributed user interfaces.

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1. Introduction

Distributed User Interfaces is an area of Human Computer Interaction exploring environments (either physical or virtual) where several devices and users are connected and collaborating.

This can be as simple an arrangement as one user and two devices (think of the growing user-base of smartphones putting computer users into a situation of possessing two computing platforms into their personal space) or a complex working environment spanning public displays, personal computers, private devices (tablets, smartphones, smartwatches) of several people working on concurrent networked tasks (think of a modern open-plan office with lax Bring Your Own Device policies).

These arrangements bring new IT challenges, not only of an organizational kind, but also those that interest the science of HCI, such as how to interact and collaborate on data living 'in the cloud' being handled through a multitude of devices with differing interface capabilities.

Shmorgun [37] surveyed the existing literature for DUIs in 2014 in search of existing methods, approaches and challenges in the design of DUIs. Of a corpus of 105 reviewed articles, 35 described one or more interaction techniques applied to multi-display environments.

Our main goal with this further exploration was to synthesize these techniques into a catalogue of design patterns, reusable solutions to recurring design problems, not in the form of code snippets but as templates or descriptions on how a problem has been solved in the past.

Design patterns have become a common practice in computer science since Gamma et al. (commonly referred to as the “Gang of Four”) published “Design Patterns: Elements of Reusable Object-Oriented Software” in 1995 [38], but they originated in 1977 with a book by architect Christopher Alexander called “A Pattern Language: Towns, Buildings, Constructions” [39].

According to Dearden [40] the main difference between Alexander’s pattern language and the GoF’s pattern catalogue is that the GoF’s patterns show some interrelationship, but stop short of forming a language in Alexander’s sense, where every pattern comes from other patterns and leads to yet another set of patterns, in a hypertext where the relationship between patterns is as much part of the language as the patterns themselves.

A secondary goal of this research was to, after cataloguing all patterns, establish how they connect to each other in an attempt to build a pattern language out of this catalogue.

2. Procedure

2.1. Building a catalogue

A Semantic MediaWiki was built to collect all the interaction techniques identified previously by Shmorgun [37]. Semantic MediaWiki is an extension to MediaWiki, the same software that enables the existence of Wikipedia for example, but expands its content management capacity through *semantic annotations* which allow machine processing of the data within. These annotations make it compatible with the Semantic Web, a W3C collaborative effort in making data in web pages shareable and reusable across different applications through a common framework. This allows any researcher to explore new relationships in the pattern catalogue using the Resource Description Framework [42] instead of resorting to manual data re-entry.

The catalogue's wiki can be found at `http://idlab.tlu.ee/patterns/`

Using an extension called Semantic Forms, the following characteristics of each interaction technique were gathered into the wiki, initially:

2.1.1. Summary

A simple paragraph describing how the interaction technique works in general terms. A quick reference for whoever is browsing the catalogue to see if this fits within their design problem without needing to read through the entire pattern.

2.1.2. Description

A more in-depth exploration of the technique as described in the original research, describing all the gestures involved and their results. Allows the reader to implement their own crude facsimile of the original technique without going into coding and implementation details (which can be found in the original research instead)

2.1.3. Reference

Points to the original article where the interaction technique was first described, allowing the reader to further explore its context and implementation.

2.1.4. Design Motivation

Collects the main research topics identified in our previous research: Creating technological infrastructure, Augmenting existing practices, Designing new types of interactions and Creating engaging experiences and Supporting the design process.

2.1.5. Design Goal

Collection of the main challenges addressed by distributed interfaces, as identified in Shmorgun [37]: Creating integrated workspaces, Improving information management across devices, Unifying the advantages of different devices, Fostering collaboration, Supporting joint interaction with information across devices, Supporting interaction in a free manner and Supporting the design of interfaces for dynamic collections of devices.

2.1.6. Enabling technologies

Listing of DUI-related technologies that are applied in one or more of the interaction techniques surveyed: Displays, Multimedia, Alternative forms of input, Low-power high-performance processors, Networking technologies, Web technologies, Sensors, Physical object identification, Haptics, Machine-readable data formats and Databases.

2.1.7. Device type and Foreseen Usage Location

Devices types include Private (usually smartphones or PDAs), Semi-private (tablets, laptops, or any other devices with a larger screen that is meant to act as a personal device, but can be easily shared by at least 2 or more people in a small group), and Public devices (usually large screen displays or digital signage). Likewise, Foreseen

Usage location takes into consideration the context of use: private - between two or more of your own devices; semi-private - for sharing between devices in the same household or a small gathering of users or public - for sharing in a meeting room, office environment or other public space where private, semi-private and public devices share a common networking environment.

2.1.8. Diagram

A visual representation of the interaction technique. Worth a thousand words.

2.1.9. Example

A real-life implementation of the interaction technique, extracted from the original research or, in cases where broadly available, from other sources.

According to Fincher and Windsor [41] there are four principles that should guide a pattern language: it should have a taxonomy so a reader can find patterns; it should allow readers to navigate to related patterns; it should allow for evaluation of problems from different standpoints and it should be generative, allowing users to develop new solutions. The pieces of information added to the wiki were enough to describe individual design patterns but fell short of a true pattern language because they did not present any relationship between patterns - it lacked, therefore, a taxonomy and the means to navigate to proximal patterns. To enable the transition from catalogue to language, we needed to supply these tools.

2.2. Taxonomic survey

Dearden [40], in its survey of HCI design languages, identifies three possible relationships between patterns: derivation - where one pattern inherits elements from a higher level pattern, aggregation - where one pattern is contained within another pattern and association - where one pattern uses another.

This leads to two types of relationship organization between patterns: either a pattern 'enables' other patterns or it 'completes' other patterns. If we were to analyze how one article describing an interaction technique cites and is cited by other articles in the same corpus, we would find the same type of relationships: earlier articles enable future articles citing it, further research by the same team completes past research and so forth. We decided, then, to base our taxonomy on bibliographic citations.

To do so, we trawled the ACM Digital Library search (available at `http://dl.acm.org`) for each of the articles singled out in Shmorgun [37]. For each article, the ACM references list was then searched for the titles of the other 34 article. Alternatively, Google Scholar (`https://scholar.google.com`) was used when an article could not be found in the ACM Digital Library catalogue.

The resulting survey of all 1190 permutations can be found in Fig. x. For clarity, the numbers used to label each article throughout this analysis match their citation numbers in this paper.

2.2.1. Initial Relationship Matrix

		Articles cited																		
		1	2	3	4	5	6	7	8	9	10	13	14	15	17	20	21	23	24	25
Shuffle, Throw or Take it	2	✓																		
Hyperdragging	3	✓	✓																	
ConnecTables	4	✓		✓																
That one there	5	✓																		
Drag-and-pop/-pick	6	✓	✓	✓																
Bumping	7	✓			✓															
SyncTap	8	✓		✓		✓														
Touch-and-Connect	9	✓																		
Stitching	10	✓		✓	✓	✓		✓	✓											
Interface Currents	12		✓				✓													
The Vacuum	13	✓	✓				✓				✓									
tranSticks	14	✓				✓		✓	✓	✓										
MuitiSpace	15			✓				✓	✓											
Ubiquitous Graphics	16			✓																
E-conic	17			✓							✓									
Select-and.Point	18	✓											✓	✓						
Slurp	19	✓																		
Chucking	20	✓	✓			✓	✓				✓	✓			✓					
Codex	21				✓						✓									
Lift-and-Drop	22	✓																		
F-Formations	23							✓						✓		✓	✓			
Conduit	24	✓		✓	✓				✓		✓						✓			
DisplayStacks	25				✓			✓			✓						✓			
EasyGroups	26							✓	✓		✓		✓							
MobiComics	27							✓	✓		✓									
MobiES	28			✓							✓									
PaperVideo	29	✓						✓												
Pinch	30				✓			✓			✓									
Seamless Interaction	32			✓											✓					
Cross-Device Drag+Drop	33	✓		✓																
VisPorter	34	✓												✓				✓		
Conductor	35	✓		✓				✓			✓							✓		✓

Fig. x. Rows represent citing papers, columns represent cited papers.
Papers with no citations skipped for brevity.

2.2.2. Social Network Analysis

This relationship matrix was then imported into Gephi, an open-source social network analysis tool. This allowed us to run several Force-directed graph drawing algorithms on the dataset to visualize the relationships between articles.

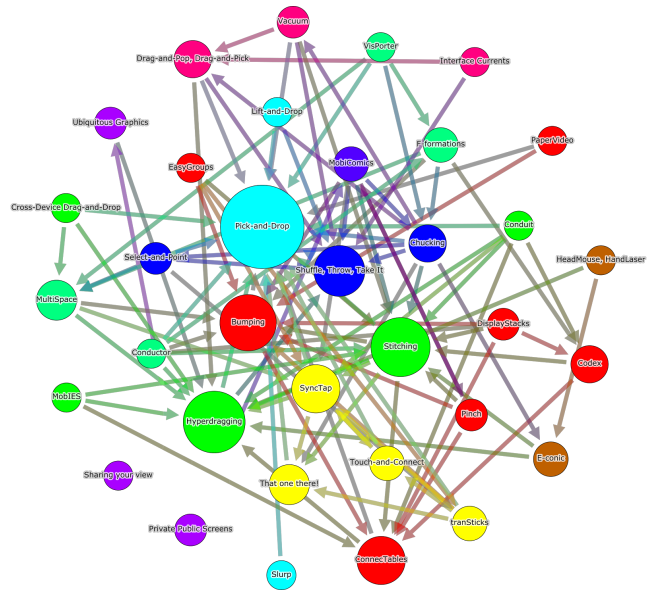
The purpose of these algorithms is to position the nodes of a graph (in our case, articles describing interaction techniques) in space so that all the edges (citations between articles) are of more or less equal length and there are as few crossing edges as possible. This is done by assigning forces among the set of edges and the set of nodes, based on their relative positions, and then using these forces either to simulate the motion of the edges and nodes or to minimize their energy. Being physical simulations, these algorithms allow visualizing social network graphs without applying any complex graph theory transformations to the data.

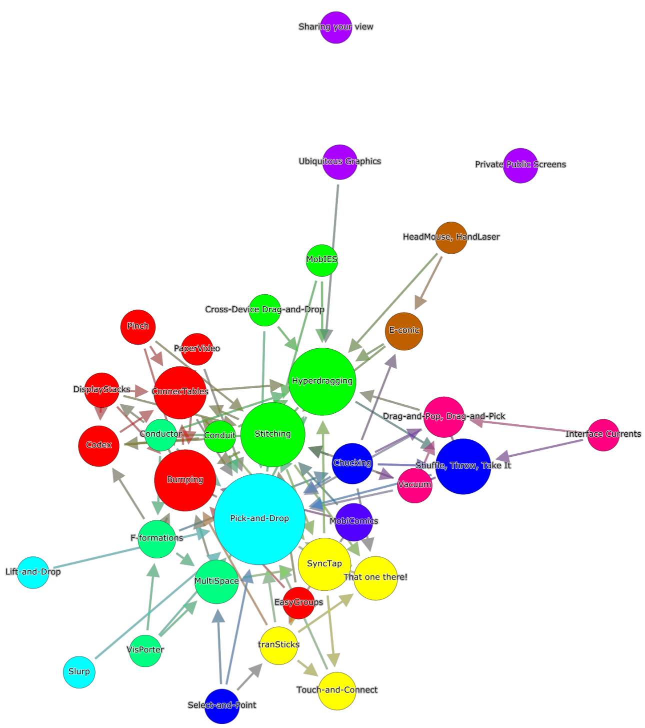
Jacomy [43] compares three different such algorithms, Fruchterman-Reingold, one of the pioneering algorithms in the area, described by TMJ Fruchterman and EM Reingold in 1991, Yifan Hu, created by Dr. Yifan Hu for Wolfram Research in 2005 and their own, ForceAtlas2, the default algorithm in Gephi.

The main strategic difference between the three is that Fruchterman-Reingold - being too resource-consuming - does not iterate, running once then stopping. Yifan Hu is able to run at variable speed thanks to its analysis of the variation of global energy in the graph; it therefore cools down after a while and settles to an arrangement. ForceAtlas2 runs continually and never reaches a cooldown, but can be interrupted by the user at any time.

We ran the same three algorithms on our dataset and the results can be seen in Sections 2.2.2.1 to 2.2.2.3.

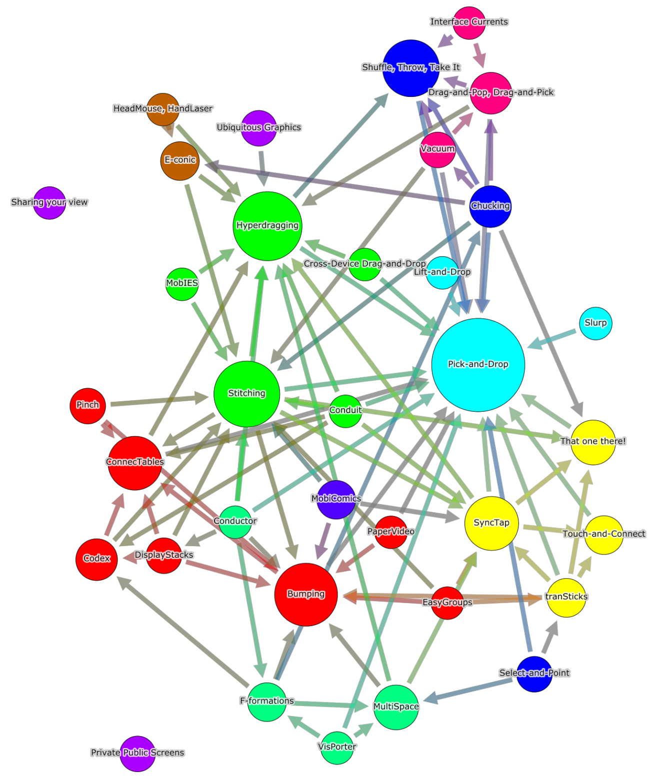
2.2.2.1. Fruchterman-Reingold. Colors were added later to represent our current understanding of how the articles are grouped. It's fairly evident that Fruchterman-Reingold was unable to group the articles in any fashion, instead just gravitating the largest nodes towards the center and the smaller ones to the periphery. Nodes are scaled according to their In-Degree, which is the amount of incoming edges connected to it or, in our dataset's case, the amount of citations an article receives from other articles in the corpus.





2.2.2.2. Yifan Hu. After cooldown, two unconnected nodes had drifted completely away from the cluster. Groups are a lot more evident than on Fruchterman-Reingold but there are still too many articles belonging to unrelated groups in the same clusters while related articles are sometimes too far away. Also, the lack of repulsive forces clusters strongly-connected nodes too close together - this makes the edges too difficult to make out, making citation analysis cumbersome.

2.2.2.3. ForceAtlas2. The algorithm was allowed to run for a few minutes, until the repulsion forces cooled down completely. The same two articles drifted away from the main cluster. Some groups are better defined than on Yifan Hu while others are more poorly defined. In this regard, they rate very similarly. Repulsion forces, though, operate in a much more acceptable fashion in ForceAtlas2: strongly connected nodes are still clustered closer together but, the more edges crossing the same area, the more repulsion applies, allowing even edge-heavy regions of the graph to be properly analyzed.



In the end, just as described in Jacomy [43], ForceAtlas2 married the clustering capacities of Yifan Hu to the force balance of Fruchterman-Reingold, but it still failed to give us meaningful understanding of the taxonomy of the articles. It became apparent the need to move to a deeper taxonomic analysis, instead of simply mapping all citations.

2.2.3. Refining the Taxonomic Analysis

We decided to analyse how each article cited each other, separating citations in two groups:

- **citations in passing**: the authors analyzed the existing literature on the subject, but the article described something different from what they were aiming at;

- **influential material**: the authors based one or more characteristics of their design on this previous article or their work was a continuation of research described in the previous article.

These criteria satisfy two defining tenets of a design language: it deepens our understanding of *derivation*, *aggregation* and *association* as described by Dearden [40] and it encompasses the generative principle from Fincher and Windsor [41] by analysing how one pattern creates further patterns.

Of the 93 citations identified in our taxonomic survey, 53.76% were deemed citations in passing and 46.24% were considered true influential material. Additionally 13 instances of *association without citation* - situations where two interaction techniques were clearly related but did not cite each other or any related article in the corpus - were identified, mostly situations where research was being done in parallel and reached similar results.

The new relationship matrix can be seen in Fig. X.

These citations were weighted by relevance - 1.0 for *influential material*, 0.5 for *association without citation* and 0.3 for *citation in passing*, and fed into Gephi for analysis.

		1	2	3	4	5	6	7	8	9	10	13	14	15	17	20	21	23	24	25	27	30	31
Shuffle, Throw…	2	✓																					
Hyperdragging	3	❝	✓																				
ConnecTables	4	❝		❝																			
That one there	5	✓																					
Drag-and-pop…	6	❝	❝	❝																			
Bumping	7	❝			✓																		
SyncTap	8	❝		✓		✓				✦													
Touch+Conn.	9	✓							✦														
Stitching	10	✓		❝	❝	❝		✓	✓														
Interf. Currents	12		❝				❝																
The Vacuum	13	❝	❝				✓				❝												
tranSticks	14	❝				✓		✓	✓	❝													
MuitiSpace	15			❝				❝	❝														
Ubiq. Graphics	16			❝																			
E-conic	17			❝							❝												
Select-and.Point	18	✓											❝	✓									
Slurp	19	✓																					
Chucking	20	❝	✓			✓	❝				✓	❝			❝								
Codex	21				✓						✓												
Lift-and-Drop	22	✓																					
F-Formations	23							❝						✓		✓	❝						
Conduit	24	✓		❝	❝				✓		✓						✓						
DisplayStacks	25				❝			✓			✓						✓						
EasyGroups	26							✓	❝		❝		❝										
MobiComics	27		✦					✓	❝		❝					✦						✦	
MobiES	28			❝	✦						❝												
PaperVideo	29	❝						✓															
Pinch	30				✓			✓			✓										✦		
Private Public Sc.	31																				✦		
Seamless Interac.	32			❝											✓								
Cross Device D…	33	❝		✓										✦									
VisPorter	34	❝												❝		✦		❝	✦				
Conductor	35	❝		❝				✓			✓			✦				✓		❝			
Sharing your V…	36																						✦

Fig. x. Rows represent citing papers, columns represent cited papers.
[❝] are citations in passing, [✓] are citations with significant contributions to the citing paper, [✦] are associations without citation. Papers with no citations skipped for brevity.

The effort paid off - a fairly straightforward grouping structure arose from running ForceAtlas2 on this weighted relationship matrix, allowing us to identify not only what articles were central concepts but also which ones gravitated around these. The divisions were so clear-cut that very few articles were included in more than one group, all of them describing groups of interaction techniques instead of a single one. The result of the ForceAtlas2 analysis is illustrated in Fig. X.

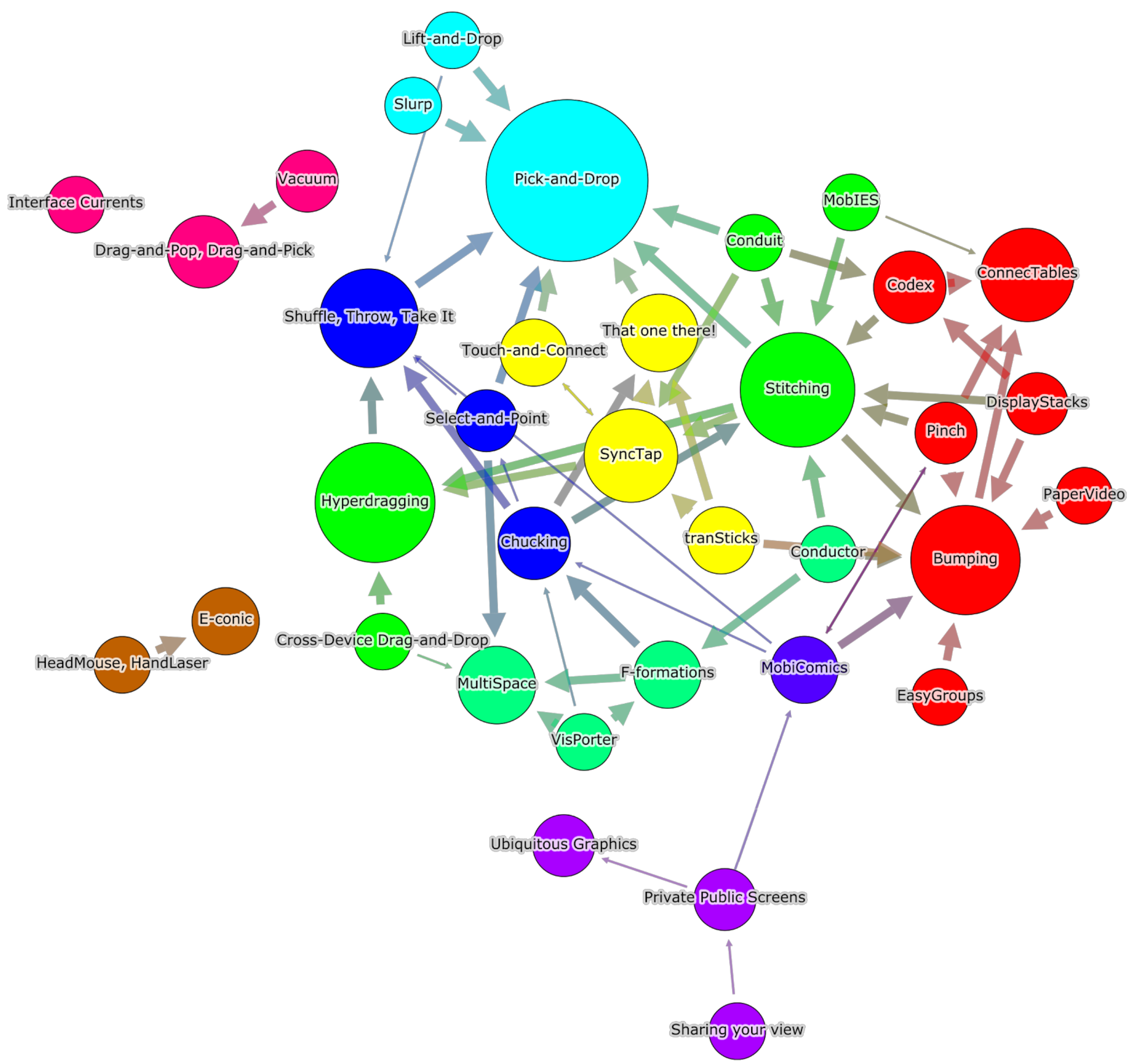


Fig x. ForceAtlas2 on the new relationship matrix. Edge weight is visible in arrow scale, weights lower than 0.5 hidden for clarity.

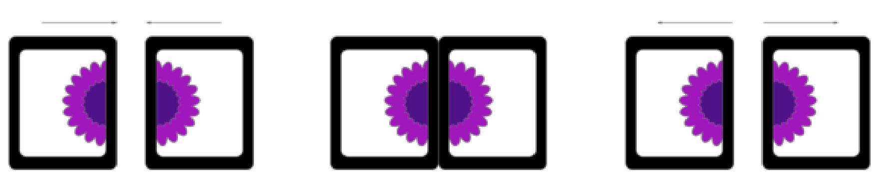
This new weighted approach led to a change in the data presented in the pattern catalogue - see the example on the next page - three new fields were added to the input form:

- **Cites:** All articles in the corpus cited by the one where the technique is described;
- **Cited by:** All articles citing it, regardless of the weight;
- **Related to:** Citations of influential material to or from said article, plus any instance of *association without citation*.

2.2.4. Example of a pattern from the catalogue

Bumping

Summary	2 tablets can be bumped together to trigger dynamic tiling of their displays. Picking up a tablet disconnects the displays. Holding the tablets at an angle during the bump triggers pouring data from one device to another.
Description	Hinckley (2003) proposes the use of a bumping gesture to dynamically connect together 2 tablet computers and form an extended screen area from the screens of individual devices when they are positioned next to each other. Removing one device from proximity reverts both screens to their previous individual state. The devices go into screen extension mode if both of them are resting on a desk. The same gesture triggers information transfer if both devices are instead being held. Bumping both devices together results in mutual sharing of information, however having one device slightly tilted during a bump results in one-way sharing of the titled device's clipboard to the receiving device.
Design motivation	Designing new types of interactions, Creating engaging experiences
Design goal	Creating integrated workspaces, Improving information management across devices, Supporting joint interaction with information across devices, Supporting interaction in a free manner, Supporting design of interfaces for dynamic collections of devices
Device type	Private, Semi-private
Enabling technology	Displays, Networking technologies, Sensors
Foreseen usage location	Private, Semi-private
Reference	Hinckley, K. (2003, November). Synchronous gestures for multiple persons and computers. In *Proceedings of the 16th annual ACM symposium on User interface software and technology* (pp. 149-158). ACM. doi:10.1145/964696.964713 [7]
Cites	Pick-and-Drop [1], **Hyperdragging [4]**
Cited by	**Stitching [10]**, **transSticks [14]**, Ubiquitous Graphics [15], F-Formations [23], **DisplayStacks [25]**, **EasyGroups [26]**, **MobiComics [27]**, **PaperVideo [29]**, **Pinch [30]**, **Conductor [34]**
Related to	Hyperdragging [4], Stitching [10], transSticks [14], DisplayStacks [25], EasyGroups [26], MobiComics [27], PaperVideo [29], Pinch [30], Conductor [34]
Diagram	



2.3. Grouping interaction techniques

Once the techniques and their relationships had been mapped, it became possible to group them according to their connections and the similarities between them. These groups represent, in a certain sense, higher order patterns which give some grammatical sense to how patterns relate to each other. Very few techniques belong to more than one group at the same time - these are emphasized in *italics*.

The nine major groups identified were:

2.3.1. Pick-and-drop

All techniques in this group share a common theme - instead of attempting a cross-device gesture, they achieve data transfer between devices through the use of a physical proxy - a stylus, an eyedropper or the user's own hands. Depends on a central server to capture the picking gesture, remembering what objects were picked by whom and then arranging the transfer of said objects to the receiving device.

Seminal article: Pick-and-drop [1]

Other members: *Shuffle, Throw or Take It* [2], Slurp [19], Lift-and-Drop [22]

2.3.2. Throw

Techniques in the group make use of a common gesture - mimicking the physical throwing of an object across devices. This technique was dormant for ten years, from the moment Geißler described it in 1998 as a method to replace long-distance dragging to the moment Lee used cameras to identify pointing in 2008. More recently accelerometers on the sending devices have been used to identify the throwing (or chucking) gesture.

Seminal article: *Shuffle, Throw or Take It* [2]

Other members: Select-and-point [18], Chucking [20], MobiComics [27]

2.3.3. Cross-device dragging

Contrary to Geißler throwing things around, Rekimoto in 1999 described a technique for continuously dragging objects between several networked devices through the use of camera tracking for positioning devices spacially. The technique took flight in 2004 when Hinckley used his previously described synchronous gestures to bind devices on a continuous dragging operation - most follow up techniques descend from this development.

Seminal article: Augmented Surfaces [3]
Other members: Stitching [10], Conduit [24], MobiES [28], Cross-Device Drag-and-Drop [33]

2.3.4. Display grouping

The largest group overall brings together techniques for joining two or more devices in a single working group. Tandler in 2001 used special sensors aligned to the edges of mobile displays to detect connection, but further techniques use synchronous gestures such as bumping devices together, pinching between two screens and even camera tracking of devices for grouping.

Seminal article: ConnecTables [4]
Other members: Bumping [7], Codex [21], DisplayStacks [25], EasyGroups [27], PaperVideo [29], Pinch [30]

2.3.5. Wireless physicality

A group that also describes techniques to joint two devices, but differentiates itself from the Display grouping techniques by the use of a physical proxy for the joining gesture: Swindells used in 2002 a special pointing stick bound to a device and capable of reading other device identifiers. Later techniques use from buttons on the devices themselves to specially bound memory sticks.

Seminal article: That one there! [5]
Other members: SyncTap [8], Touch-and-Connect [9], tranSticks [14]

2.3.6. Gravity-like

Not all relationships are born out of success: the defining characteristic between the techniques in this group is their discontent with the imprecision of Geißler's throwing gesture (all techniques were described before Lee resurrected throwing using cameras in 2008). The solutions vary slightly, but all use gravity-like forces to either attract targets closer to the dragged object or to move objects around like a stream.

Seminal article: Drag-and-Pop and Drag-and-Pick [6]
Other members: Interface Currents [12], The Vacuum [13]

2.3.7. Cross-device portals

Instead of demanding a cross-device dragging gesture to transfer information between devices, the techniques in this group resort to portals, visual proxies of other devices in the group, through which objects can be transported. First described by Everitt in 2006 in a table-centric interface that had fixed portals representing other displays in the group, it was further expanded, mostly through the use of proxemic techniques, to make dynamic use of portals that only present themselves when other devices are around. Also included is the concept turned on its head, where a device broadcasts an intent to share to all devices in the group for one or more recipients to accept [35].

Seminal article: MultiSpace [15]
Other members: F-formations [23], VisPorter [34], Conductor [35]

2.3.8. Private Public Screens

Techniques in this group combine a shared, public screen displaying coarse information with private screens where this information can be handled in depth - by pointing the private device to a portion of the public screen, it captures the information and displays it in more detail than is being shared publicly. Sanneblad used a digital whiteboard's sonic tracking pens in 2006 for this purpose, but later implementations use other forms of near-field radio (NFC, RFID) or visual (QR-Codes, image interpretation) techniques to the same effect.

Seminal article: Ubiquitous Graphics [16]

Other members: VideoWall [31], Shared Views [36]

2.3.9. Perspective-Aware

These techniques compensate for user position relative to one or more devices when drawing interface elements. Nacenta used camera tracking in 2006 to locate users in space and draw objects relative to their visual position, then project these onto screens in the environment to allow for better readability and easier interaction. It was further explored in 2013 when a group of different interaction techniques were tailored and tested for these perspective-aware displays.

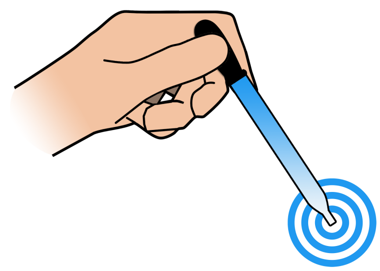
Seminal article: E-conic [17]

Other members: Seamless Interaction [32]

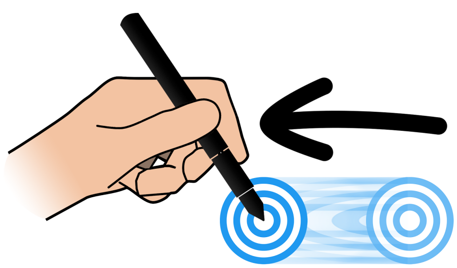
2.4. Recurring gestures

While each of these techniques can be added to one or more interaction groups, they are sometimes comprised of gestures that occur in other unrelated techniques. The following is a list of gestures that occur in one or more interaction techniques, sometimes under different names:

Picking: the act of removing an object from a device to later drop it somewhere else. also called **taking**, **extracting** and (air)**lifting**.

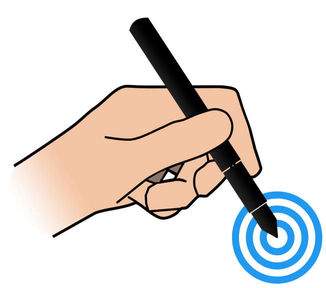


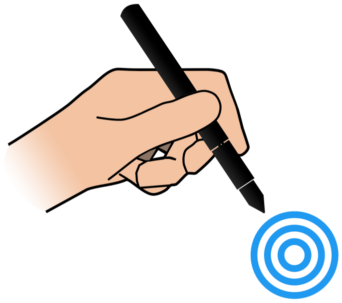
Dragging: pressing the mouse button, finger or stylus tip against an object and moving it in a certain direction, usually followed by **dropping** (releasing the button or lifting



the stylus or finger). When done across screen borders can be called **stitching**. **Dropping** can be called **popping** when the targets are under influence of gravity-like effects, as in drag-and-pop - these targets will then pop back to their original places.

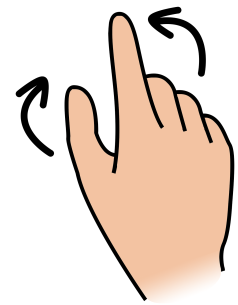
Tapping: pressing the mouse button, your finger or the tip of a stylus against an object, then releasing. Also called **clicking**, **touching** and **selecting**.





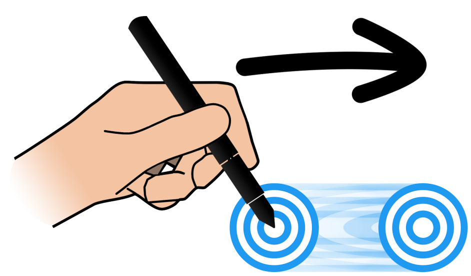
Pointing: using the tip of a wand, stylus or your finger to indicate an object without actually touching it. Depending on the technology behind the detection may need to be done from a certain distance (sometimes called **hovering** [13])

Pinching: moving two fingers towards one another. Both fingers can be on the same device or on different devices, pinching towards borders that are touching each other.

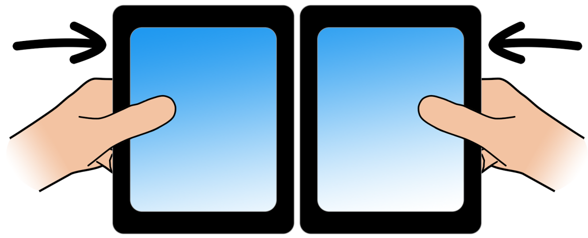


Throwing: sending an object from one place to another by mimicking the act of throwing it. Originally done by dragging towards you then, without dropping, dragging away from you and dropping. It is sometimes called **flicking** [27]. Later appropriated to mean selecting an object on a device and then mimicking physically throwing towards the target (also called **chucking**).

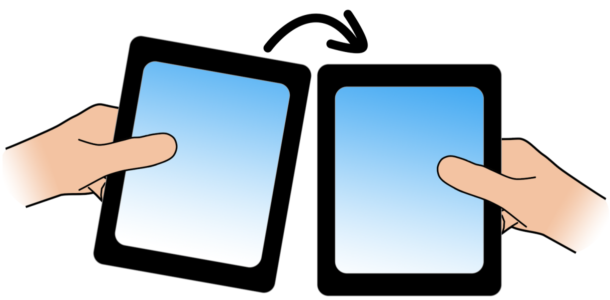
Shuffling: dragging sideways across an object's handle in order to move it sideways. A special case of throwing, dormant for over a decade.



Bumping: bringing two devices physically together. Can be done side against side (**collocation** [25]), corner against side, corner against corner with different results.

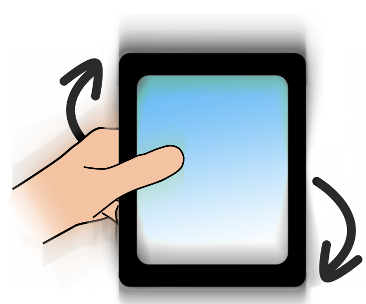


Tilting: angling your device (usually 10 degrees or more) in relation to another device. Tilting towards a device can be a gesture of sending or sharing content (called



pouring) and tilting away from a device can be a gesture for pulling content (called **retrieving**). Tilting a device so its screen faces another device's screen can be a gesture for mirroring content (called **facing**).

Flipping: turning a device's screen 180 degrees from facing upwards to facing downwards or vice-versa. An extreme example of tilting but not done in relation to other devices. Also used to cancel actions.



Stacking: putting several objects on top of each other. When disorganized, can be called a **pile**. Like a hand of cards, can also be *linearly overlapping* or spread like a *fan*.

Shaking: holding an object and moving it in short, rapid sideway movements. Usually done to cancel an action or delete content.

2.5. Micro-Patterns

Through the processes of grouping patterns and identifying common gestures that occur time and again in Multi-Display Environments, we were able to identify what we have termed micro-patterns, that is, the minimum, indivisible actions or techniques that enable the interaction techniques present in our catalogue. It is by applying or combining these micro-patterns into practical interaction models that the patterns in our catalogue have emerged. The micro-patterns we have identified are:

2.5.1. Screen Mapping

An interaction technique applies this micro-pattern every time it needs awareness of how many screens are present in an MDE and where they are present absolutely in space or relative to each other. This is one of the most basic micro-pattern in any interaction technique involving more than one screen.

2.5.2. Screen Merging

A derivative of screen mapping, it's applied every time a user interface temporarily or permanently spans more than one screen. It's enabled by **Screen Mapping** and is the main enabler of the **Display Grouping** pattern group

2.5.3. Synchronous Gestures

A rather complex concept hiding behind the simplicity of its results, **it** is a micro-pattern that's applied every time a gesture begins at one device and moves into another without them being previously mapped together. By identifying that two synchronous gestures in different devices are actually a single gesture spanning two devices, it is possible to infer these devices are contiguous and apply **Screen Mapping** to them.

2.5.4. Group-based Micro-patterns

The following micro-patterns emerged from analysing how other patterns grouped together: they mostly share a name with their group:

Portals: This micro-pattern is applied every time an interaction technique uses a proxy to represent one device on the interface of another design. The main enabler of **Cross-device portals**, this micro-pattern can be combined with a multitude of gestures such as flicking or drag-and-dropping to allow remote interaction with/data transmission to a device without interacting directly with it.

Gravity-Like: This micro-pattern applies to all interaction techniques where not all forces being applied to objects are being exerted by the user. These “nature-like” forces: gravity, magnetism, attraction, flow, etc. allow interface components to move around without explicit, direct control of users. Main enabler of **Gravity-like** interaction techniques.

Private Public Screens: Whenever a private device is used to see details of data presented in a coarser form on a public display is an instance of this micro-pattern. Very closely related to Augmented Reality in that what you see through your private device is an augmentation of what others see on public displays. Enables the **Private Public Screens** group.

Perspective-Aware Interfaces: When multi-display interfaces take into consideration the observer’s perspective when drawing interface elements you have an instance of this micro-pattern. This increases readability for the users whose perspective is being tracked but, if applied to public displays, can make interface elements unreadable to everyone else. Enables the **Perspective-Aware** group.

2.5.6. Gesture-based Micro-patterns

Besides all the micro-patterns exposed above, some patterns depend explicitly on common, recurring gestures such as **pointing**, **bumping** or **throwing.** When two or more patterns depend on one such gesture, we've also mapped them as micro-patterns.

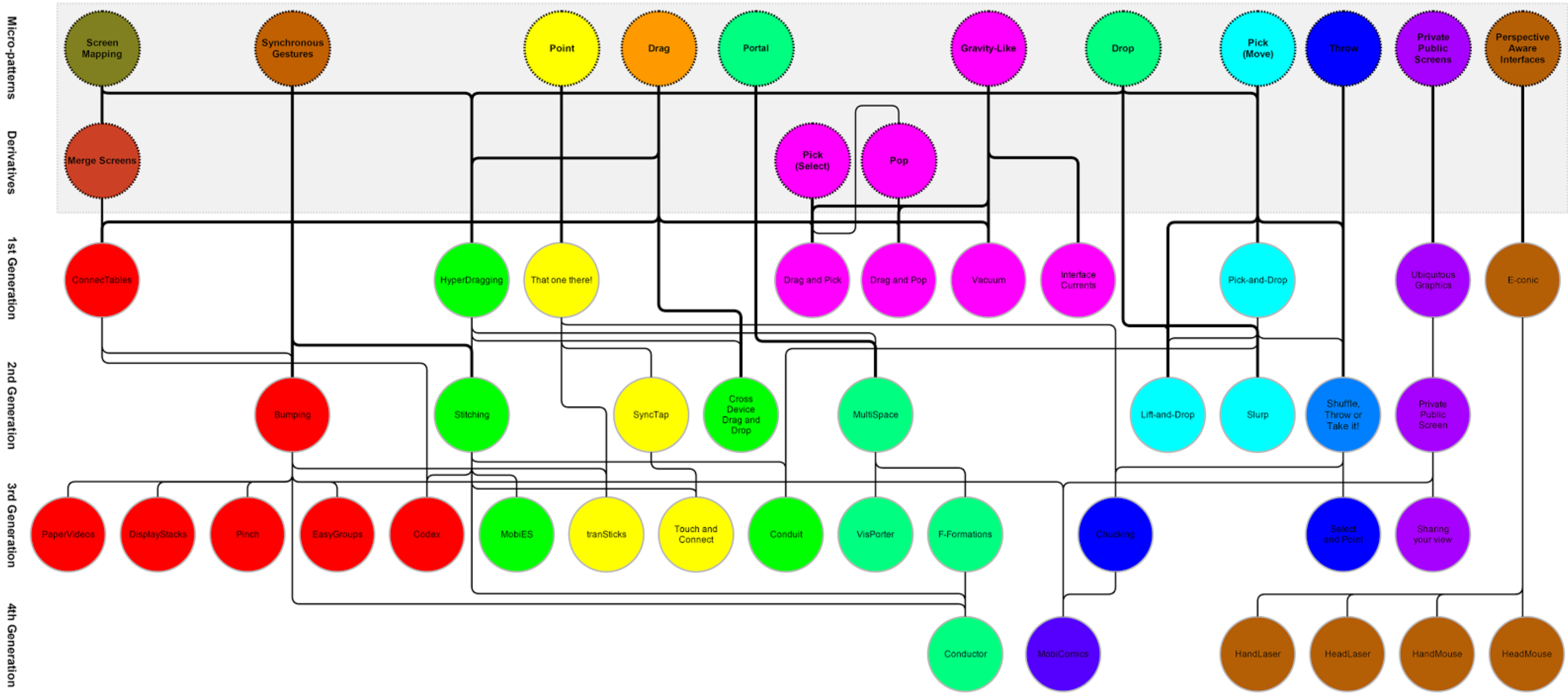


Fig. x - Subtitle goes here, no idea what to put here

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