Towards a Toolkit for Practising Experience Designers: Methods for Identifying, Conceptualising, Characterising, Measuring and Implementing Interactivity

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Declaration

I herewith declare that I have produced this dissertation without the prohibited assistance of third parties and without making use of aids other than those specified; notions taken over directly or indirectly from other sources have been identified as such. This dissertation has not previously been presented in identical or similar form to any other English or foreign examination board. The dissertation work was conducted from 2009 to 2013 under the supervision of Professor Ryohei Nakatsu at the Keio-NUS CUTE Center, Interactive and Digital Media Institute, NGS Graduate School for Integrative Sciences and Engineering, National University of Singapore.

Abstract

This dissertation presents the culmination of theoretical and applied research conducted at the Keio-NUS CUTE Center within the topic of interactivity. The theoretical study and applied development of interactive experiences, artworks, products and systems requires a multidisciplinary approach. Methods, techniques and terminology can differ greatly between the practitioners that are involved. These include software developers, engineers, social scientists, interaction and experience designers, media artists and usability experts. As such, approaches towards identifying, conceptualising, characterising, measuring and implementing such systems can be fragmented and disjointed. With this in mind, this research attempts to bring parity between experience design practitioners by proposing methods that address the above mentioned activities of identifying, conceptualising, characterising, measuring, and implementing (IC^2MI) in a simple and resource-efficient manner. This dissertation is organised to address each part of the process of IC^2MI from a practiced-based perspective. Methods to address each stage are extrapolated from experiences working as an experience designer at CUTE, and are supported with case studies and experiments outlined throughout the dissertation. The methods proposed are a genealogical survey of past projects (identifying), the Blue Sky Innovation process (conceptualising), the characteristics of Analogness and Digitalness, and the Analogness-Digitalness Continuum (characterising), with future works looking towards measuring (the Interactivity Index and the Hierarchy for Interactive Systems Development), culminating in the development and prototyping of the Linetic liquid interface system (implementing). The collection of methods can be used individually, in combination with other toolkits and methods, or in chorus as a toolkit for practicing experience designers.

Acknowledgements

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To Mercedes and Eugene Koh,

for being there from the beginning,

and to Karin Aue,

for being there at the end.

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Chapter 1

Introduction

This dissertation presents the culmination of theoretical and applied research conducted since August 2009 at the Keio-NUS CUTE Center[1] regarding a multidisciplinary approach for practicing experience designers to identify, conceptualise, characterise, measure and implement Interactivity (IC^{2}MI). Using works created at CUTE Center (here by referred to as CUTE), including a novel system conceived, designed and developed specifically for the IC^{2}MI study as primary sources, I present findings from practice-based research that supports the proposed methodologies presented in this manuscript. Together these act as a toolkit for the experience designer, artist, developer and researcher. They are meant to be used with minimal effort and resources for rapid ideating, prototyping and analysis.

The theoretical study and applied development of interactive experiences, artworks, products and systems requires sometimes a significant collection of knowledge and skills, with challenges that can be solved using any number of knowledge/skill configurations across many fields of practice. Methods, techniques and terminology can differ greatly between practitioners who are interested in the topic of interactivity. These may include software developers, engineers, social scientists, interaction and experience designers, media artists and usability experts. As such, approaches to-

[1] Keio-NUS CUTE Center (http://cutecenter.nus.edu.sg/)

wards identifying, conceptualising, characterising, measuring and implementing such experiences can be challenging. In addition, research expectations depending on the field may differ. The HCI community has itself wrestled with the role of design in the research process [49]. This dissertation aims to present evidence that design research methods can be developed through practice-based enquiry, and that design methods are a valuable component to HCI research.

Of course the field of design is not devoid of its methodologies. Other fields have attempted to incorporate design methods into their work and research process [94]. Numerous frameworks, methods and techniques for any stage of a project are available to the researcher and practitioner [8]. Most of these can be used on their own or in conjunction with one another and are proven as reliable sources of data to some measure of degree [83]. Often the most cutting edge methods from fields such as usability testing employ complex systems such as eye tracking [115] or even biological feedback [47], inherited from other fields of research and practice, such as the social and life sciences.

Some in-practice research techniques employed by practitioners such as designers are often much more rapid in their conceptualisation and prototyping cycles. This practice is similar to research and development practices in hacker/maker-style academic research laboratories such as MIT Media Lab[2] and the Keio-NUS CUTE Center. Some of the techniques employed by these engineering, computer or social science, and design-led research institutes include participatory design [123], narrative design [57] and design thinking [10]. Yet even with the deployment of such design-based techniques, research outcomes from the design field methods of inquiry and analysis are often seen as secondary, especially in the HCI and related fields [49].

From considerations derived from the subsequent research to be presented, there are some experiential differences between a practicing designer working for a client

[2]MIT Media Lab (http://www.media.mit.edu/)

or agency, and the designer who works in the academic research setting. In the case of the designer working freelance or in an agency, the work is much more constrained to the specifications of the brief, and always at the will of the client. Research and development cycles are also inherently shorter and more rapid. To employ any of the more intricate measuring and data collection techniques (eye tracking, biological feedback, etc.), not only is a great expertise needed, but also a considerable amount of time and resources. There are commercially available research services where these types of studies could be outsourced to[3]. Yet for the small-to-medium sized design practice, think-tank or innovation laboratory, these are rarely an option.

Therefore for in-practice design practitioners, a need for a more streamlined and efficient research and development workflow is required. Workflows that offer insight into the user using design thinking, human-centered design [22], narrative strategy, and other popular methods that stem from IDEO[4], Frog Design[5], Philips[6] and others, are a popular means to gain insight as all design should be in the service of the enduser. But how about gaining insight into the actual system and the symbiotic relationship that the system has with its user? How can we attribute characteristics to a system in order to describe this? Are there ways we can describe a system′s characteristics and use this as a means to develop new interactive experiences? Finally can we standardise and categorise the character description of all interactive system experiences? What are the wider implications of this? In addition to these questions, the *Background* chapter includes discussion of the problem and motivation behind the research presented throughout this dissertation.

Directly after the background is the *Related Works* chapter of this dissertation. This chapter explores the foundational works that have influenced and supported the research outlined throughout this dissertation. This includes focus towards the

[3] CSC Business Solutions, Technology and Outsourcing (http://www.csc.com/)
[4] IDEO (http://www.ideo.com/)
[5] Frog Design (http://www.frogdesign.com/)
[6] Phillips (http://www.philips.com/)

field of User Experience Design (UxD), but also includes discussion on the symbiotic relationship between user and interactive system from an embodiment perspective, as well as an assessment of usability study and toolkits in HCI.

Presentation of the research proper begins by exploring the genealogy of interactive systems developed at the Mixed Reality Lab and subsequently at the Keio-NUS CUTE Center, National University of Singapore. This body of work was chosen for its accessibility (full disclosure: at the time of writing I worked at CUTE), but also for its unique situation and approach towards research and innovation.

In regards to accessibility, in order to gain a thorough insight into the inner workings of organisations that work in similar spheres, knowledge into not only the working process is needed, but also other candid and situational factors such as organisation culture and interpersonal relationships can be useful. Because of this, using CUTE as a primary data resource is more advantageous when compared to trying to gain these insights from other labs as I was a member of CUTE from its inception to the time of writing.

Throughout its more then a decade long existence, the efforts of the centre's multidisciplinary and multicultural members have collectively developed a multitude of interactive systems. With such a wealth of interactive systems to study, as well as such a diverse group of practitioners to work with, it was only natural to use CUTE as a primary source for this research [15, 81].

In the chapter *Identifying: A Genealogy of Mixed Reality Lab Projects*, analysis of case study projects from the Mixed Reality Lab (the precursor to CUTE) are used to describe how a multidisciplinary research laboratory specialising in interactive experiences, artworks, products and systems evolves. As the first component of IC^{2}MI, identifying thematic grouping of projects and their relationships to one another was conducted in order to understand the types of interactive systems that exist, at least as developed by the Mixed Reality Lab. This chapter also looks at prototypical interactive systems, as well as the situational conditions that the lab conducts its research.

The chapter titled *Conceptualising: Blue Sky Innovation*, describes a method for project ideation and conceptualisation that was employed by the Mixed Reality Lab and Keio-NUS CUTE Center. Using Linetic as a case study, supported with other case study examples from the MXR's and CUTE's numerous works, this section outlines the core philosophy and methodology in order to practice *Blue Sky Innovation*, as well as discusses some of the drawbacks to using this practice.

The next chapter describes characteristics shared by all interactive systems in a chapter titled *Characterising: Analogness and Digitalness* [81]. First identified while looking back at earlier projects from CUTE, and later applied to help steer the design and implementation of the Linetic project [144], these characteristics can be found in any interactive scenario. With the characteristics of *Analogness and Digitalness* defined, most any interactive system can be described by these characteristics. As a tool for system development and analysis, systems can be compared to one another depending on their disposition towards *Analogness* or *Digitalness*, which can be plotted out on an *Analogness-Digitalness Continuum* (ADC), also presented in this chapter.

The next chapter discusses the *Linetic* liquid interface system, and represents the *Implementing* aspect of IC^{2}MI. Included in this are concepts, designs and experimental research data collected from the development of a haptic, organic user interface. Linetic is an interactive system designed and implemented in conjunction with the development of the methodologies earlier presented in this manuscript. This chapter also includes subsections regarding physical experiments [80], key technical contributions [67], as well as considerations from an aesthetic perspective [77].

In the *Measuring: Considering an Interactivity Index and Hierarchy for Interactive Systems Development* chapter we discuss the various avenues where this line of research could lead towards. In the first half of the chapter, we discuss a potential tool to measure all interactive systems called *The Interactivity Index*. The second half of the chapter is an initial exploration towards a *Hierarchy for Interactive System Development* [78]. The Hierarchy aims to describe, with similarities to Maslow′s Hierarchy of Needs [99], the order of importance when considering technology, content and the semantics of any user experience.

In the *Conclusion* section, we reiterate the key contributions of this dissertation, summarising the methods that were developed during this research period. Synthesised from the methods presented in each chapter, we propose an experience design toolkit that can be used by any researcher or practitioner to identify, conceptualise, characterise, measure and implement interactivity.

Chapter 2

Background

The first issue that arrises for the practice-based design researcher is that of accessibility [21]. To employ any number of the most cutting edge study techniques in fields such as HCI, either qualitatively with well groomed test groups, or quantitatively, using biometric sensors or other measurements to gain empirical evidence of body response, would take a sizeable amount of time and resources. For the practicing design researcher, this is an issue because often the work is conducted in teams that allocate very little time and resources for a design researcher to apply such methods during a rapid and iterative development phase.

Of course there are much less resource-costly experiment methods that can be employed. Usability testing is a well defined area of study. Some popular usability methods include heuristic, think-aloud and performance testing [147]. Each have some measure of success in providing feedback from a user to researcher. User-centricity is still at the root of each method however, and all three methods provide little to no direct characterisation of the the relationship of the system and user specifically. Still these methods are used as they better fit the development cycle of most projects, unless the product or service needs a thorough testing phase like that of medical equipment. For labs like CUTE, HIT Lab[1], MIT Media Lab and more, where the

[1] HIT Lab (http://www.hitl.washington.edu/home/)

development phases are much more rapid in their intervals, a better suited toolkit that is less disposed towards usability and more focused on interactivity is needed.

As identified in the *Introduction*, the employment of hacker/maker and design-based research practices in the academic research setting has afforded the design researcher a means to participate in cutting-edge research, especially if the research outcome is product or service-oriented. Design research methodologies are sought out, but the acceptance of design-based research findings by the HCI community has only just come to maturity. Conferences such as ACM DIS [133] attest to this, as well as design tracks in various conferences such as ACM CHI [152] show that design research techniques and methodologies are making headways in the field. Still some believe that expectations from design research techniques should be curbed, yet also embraced for the novelty in approach it brings to problem-solving and interactivity development [49].

In order for the design-researcher to participate at the breakneck speeds of rapid prototyping and development as employed by these hacker/maker style research organisations, concise studies that fit within the iterative workflow may gain less hard evidence for traditional research output, but more insight into the user/system relationship in order to make a product or service better or more innovative. Any sample from the various years that ACM DIS has been in existence shows papers that focus on design process and case study as opposed to purely empirical findings [157]. Again insight and iterative improvement is the goal for most design-based research methods. With this in mind more practice-based research methods as we see in professional fields such as psychology [58] as well as fine art [86] should be developed, employed and embraced by not only more design-based researchers but also the wider HCI and UxD community as a whole.

Specifically for the design researcher in the HCI and UxD communities, what is lacking in the current state of the art is a resource-efficient toolkit for iterative design processes that look at the characterisation of interactivity shared by both system and user. Resource issues include time, manpower, funding and skill acumen. From an embodiment perspective, this symbiotic relationship that essentially makes system and user an extension of one another is a phenomenon that is discussed within HCI [33], but very few tools if any exist to leverage on the understanding of this phenomenon in the design research field. Stemming from this specific gap in our tools as practicing design researchers, a toolkit based in concepts of embodiment and the activity of practice are needed. The methods presented in this dissertation hope to facilitate such a toolkit.

Therefore this research is partially based on the exploration of the embodied state of system and user as being at differing states of *oneness*, and aims at gaining insight into the actual system and the symbiotic relationship that the system has with its user. Some fundamental questions that this research asks include: How can we attribute characteristics to a system in order to describe this symbiotic relationship? Are there ways we can describe a system's characteristics and use this as a means to develop new interactive experiences? Finally can we standardise and categorise the character description of all interactive system experiences? What are the wider implications of this?

If the system is emotive and pervasive, then not only insight into the nature of the system is needed (the engineering perspective), not only is a user-centric perspective important to understand (usability, ergonomics, user-centred design), but a way to identify, describe and apply the very character traits that make a certain style of interactivity between user and system unique can also be useful.

The motivation of this research is to develop a toolkit that can be employed within rapid development and prototyping cycles, with methods that can be used separately, in conjunction with one another, or even with other techniques and methods. It should consider the relationship of the user and system from an embodiment perspective. The toolkit should encompass the entire gamut of process steps, offering a method for each step, so that a developer of interactive systems may identify existing interactive works, conceptualise new interaction styles, characterise these styles for specific uses or users, measure the nature and intensity of an interactive scenario, and implement an interactive system or experience. In all, the toolkit is a systematic, compact and efficient framework for interactive research and development that is based on two questions: *How are we doing*? and *How can we do it better*? [59].

Along with basing the toolkit in concepts of embodiment, the actual methodology employed to achieve this research goal was that of practice-based research [140]. This is of course counter intuitive to the normality of empirically-based research that is lauded in current science and engineering research and development communities. However there is a sizeable and convincing body of work far too vast to be synthesised in this humble dissertation that celebrates the merits of theoretical evidence obtained through practice-based experiences. Specifically in fields such as education [48], as well as the the previous examples touched upon above, the success of practiced-based research on foreseeing, directing and analysing research outcomes during the process of a specific practice has been proven. More so from the design research perspective then in any other research field, practice-based research occupies a borderland between the academy, commercial R&D and the cultural industries [140], and is thus a perfect fit for design research, which also occupies this grey area where academy, commercial R&D and the cultural industries meet. Because of this it is hard to fully qualify the merit of such a methodology of research from simply only one perspective (in most cases an academic one). Therefore practice-based research has had difficulties reaching a unified acceptance by traditional scholars. Still, the simple merit in applying a practice-based research model extracted from experience is essentially a primary sources of data, from an empirical perspective.

Now why would this be important for a designer working in a scientific and engineering research setting? One of the answers is that there are never enough opportunities for designers and scientists to get together. The more ways for these diverse practitioners to collaborate the better. The experience of this synthesis of practices should be documented as there are no clear methodologies or guidelines for artists, designers and technologists to formally collaborate. The designing of experiences seems to require a multidisciplinary approach and therefore an understanding of how various researchers and practitioners within the design field and beyond operate. To understand this a survey was conducted in order to inform the approach needed towards developing the toolkit proposed in this dissertation.

2.1 Survey to Understand the Similarities and Differences Between Design Researchers and Design Practitioners

A survey was conducted with the purpose of understanding the similarities and differences, if any, between design researchers and design practitioners within the context of *Experience Design*. This survey was designed using [143] as a guide. Expert participants were sourced from the design practice and scholastic research fields, working primarily in academic research institutes, as well as practicing professional from the freelance, private and commercial communities. The results and summary of this data can be found in an Appendix later in this dissertation. Raw data collected from the survey can be found at the following link [2], footnoted below.

[2] https://docs.google.com/spreadsheet/ccc?key=0AhY0aUil40MedDFMVDd0R3IyeUtCWlBvTGtLM1BCMkE&usp=sharing

Figure 2.1: Of the 42 people that completed the survey, 22 participants were male, while 20 were female (mean average of 32.59, standard deviation of 7.39, with one participant who did not provide their age.

As seen in Figure 2.1, of the 42 people that completed the survey, 22 participants were male, while 20 were female (mean average of 32.59, standard deviation of 7.39, with one participant who did not provide their age).

Questions consisted of a combination of Yes/No queries, open-ended questions as well as Likert scale questions. This combination of question styles provided a means for the collection of qualitative and quantitative data. A sample of the survey can be found in a following Appendix chapter. The survey was conducted online using Google Drive [3] and was distributed by direct email to potential participants chosen for their background and profession, as well as publicised on professional user groups in social networks such as Facebook [4] and Mendeley [5].

From analysis of the survey, several insights can be derived. This includes an understanding of a definition for the term *Experience Design*, opinions on who are experience designers, the differences between academic and commercial work environments, challenges of working in multidisciplinary teams, if there are any differences and similarities between design practitioners and design researchers, as well as a examples of workflows from practitioners and researchers along with the general skills involved in executing them.

[3]https://drive.google.com
[4]https://facebook.com
[5]https://mendeley.com

2.1.1 Defining Experience Design

For this research, the following definition from [1] was used as a contingent definition. Aarts, and Stefano define *Experience Design* as the practice of designing products, processes, services, events, and environments with a focus placed on the quality of the user experience and culturally relevant solutions. This definition bares similarity from the idea that participants in the survey have regarding the definition of experience design. Some of these include:

- Designing products or services to improve the quality of human experiences or to augment human experiences. *Male, 30, PhD Student at the National University of Singapore.*

- Facilitate conversation between user and product. *Male, 28, Assistant Professor at City University Hong Kong.*

- Experience design is the process of designing for the senses pertaining to factors such as social environment, user-interactivity, etc. *Female, 30, Senior Designer at M.inc.*

- Creating a space or environment which allows the occupants to feel and experience in a particular situation. *Female, 35, Architect formally working at OMA, Atelier Bow Wow, now Lecturer at University of Adelaide.*

- Typically it is the design of total, multi-modal experiences. I can say that I do that with other practitioners from other disciplines (e.g. fine art, film). *Male, 64, Composer and Sound Artist.*

- I would say the definition of experience designer: Designer who focuses on the interactions between the user(s) of tools, products or services. *Female, 26, Interaction Designer formally at IDEO.*

- Purposefully curating the experience that a person/visitor/customer/end user will have at an event or using goods or services, to add value and make the activity more memorable. *Female, 30, British Music Experience Education Manager and Experience Design tutor for Artscom at Central St Martins.*

- A cross disciplinary, multi-sensorial design approach taking the overall journey of the user into account and mapping it across all relevant touch-points to create one holistic experience. These experiences can have various formats in terms of size, time span or medium e.g. combining space, communication and UI design to create a exhibition or retail space. *Female, 32, Senior Designer at a design consultancy based in Singapore, formally Creative Director of Arthesia, Exhibition Designer for OMA, Senior Designer at IDEO and Designer at KesselsKramer.*

- Designing products or services that creates emotional responses. Sometimes I think it is satisfying user needs with a product or services. *Male, 30, Lead UX Designer at Honeywell Technology Solutions Lab.*

- Bringing forth a context that encourages a set of desired experiences. Designing such that the user might later hold a memory or narrative account that shares in some ways the vision the designer held in shaping an object, event, or process. *Male, 38, Assistant Professor at Aarhus School of Architecture.*

- Define users' expectation, translate them it to features or processes, select the important ones and arrange them in such a way that won't give ambiguity to users. *Male, 23, Electrical Engineer at T.Ware.*

- A well crafted process/space where everything from the biggest to the smallest has been considered (and designed). It's about preempting and anticipating people's reactions, feelings and responses to their surroundings and ensuring that there is no void or glitch in the process where the user/person is unhappy or annoyed. Seamless, smooth, functional and sometimes wows. It's also about conveying a message (e.g. a brand) at every single touchpoint, again not leaving anything to chance, in order to ensure the bigger message and desired atmosphere is conveyed. *Female, 33, Senior Designer at Chemistry Pte. Ltd.*

- Design something for the end user taking into consideration all the touch points and designing it for being a whole and consistent experience that would be memorable. *Female, 31, Senior Design Researcher at Asus.*

- Experience design is about delivering a cohesive set of interactions from an end user point of view across a particular 'journey'. The experience should ideally address all facets of the mind and all senses as and when appropriate. It should work to resolve the end users's known needs and challenges and in addition bring an element of new and unexpected experience that will create an enduring memory of that experience. *Male, 39, Formally Design Account Manager and Senior Design Consultant at Philips Design, currently Creative Director at Chemistry Pte Ltd.*

As seen in Figure 2.2 A weighted list was generated using all survey responses pertaining to the question *What is your definition of experience design?* at Wordle [6]. Major terms that were shared across many of the definitions include interaction, environment, people, products, process, service and user take precedence when defining Experience Design.

When comparing the various definitions it is apparent that experience design requires a multidisciplinary collection of skills and practitioners. This is confirmed by the variety and amount of practitioners that all agreed to significant degree (100% of the 41 participants answered positive when asked *Can you consider the work you*

[6] http://www.wordle.net/

Figure 2.2: A weighted list containing the major keywords from the responses to the question "What is your definition of experience design?" shows that the terms interaction, environment, people, products, process, service and user take precedence when defining Experience Design.

engage with to be the designing of experiences?) that their work involves the designing of experiences.

2.1.2 Who are Experience Designers?

In regards to education, 23 of the respondents achieved the Master degree level (55%) while the remaining participants were closely divided between achieving a Bachelor degree or Doctorate degree. 9 participants had Doctoral degrees (21% of the participants) and 10 had Bachelor degrees (24% of participants). This is represented in Figure 2.3. The majority amount of graduate-level degree holders indicates that most

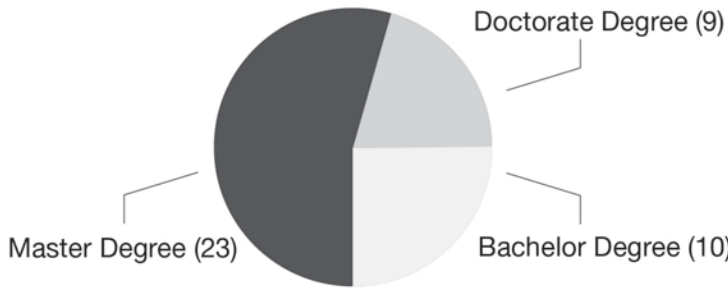

Figure 2.3: Total result of responses when asked *What is your level of education?*

participants were familiar, at least on a rudimentary level, with a basic conceptual understanding of research, which *comprise(s) (of) creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications.* [45].

From choosing a selection of expertise types, 48% of participants (20 responses) considered themselves from the Design field, 36% from the Science and Technology field (15 responses), 10% from the Fine Arts (4 responses), 5% from the Social Sciences (2 responses), 2% from the Humanities (1 response), and 0% from Business (0 responses), with zero respondents choosing from the item field *None of the Above.* This is represented in Figure 2.4. Of the expertise types offered in the survey, the majority of respondents were either from a design or a science and technology background. This hints at the further need to develop parlance, methods and tools that are usable by researchers and practitioners from these two backgrounds. It is also worth noting that these two areas of expertise are converging, partly due to the need for both aesthetic and software development skills required of contemporary UX designers, and HCI computer scientists and engineers, in a world that is increasingly migrating to online and mobile services with the user at the centre of the equation [7].

[7] Why The Valley Wants Designers That Can Code. http://www.uie.com/brainsparks/2011/05/31/why-the-valley-wants-designers-that-can-code/

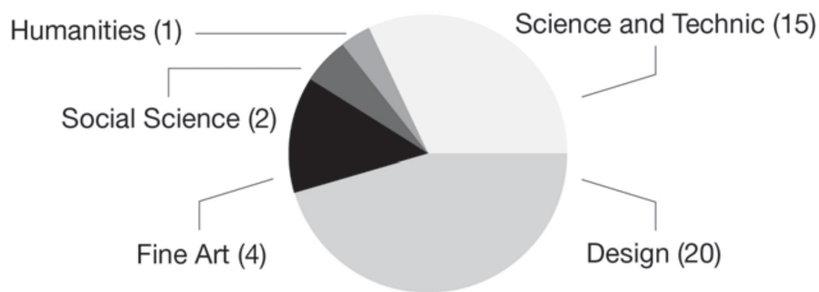

Figure 2.4: Total result of responses when asked *What is your area of expertise?*

When asked whether they think themselves to be designers, researchers and/or practitioners, 30 out of 42 respondents indicated that they considered themselves designers (71%), 30 out of 42 respondents indicated that they considered themselves researchers (71%), and 41 out of 42 respondents indicated that they considered themselves practitioners (98%). These responses are represented in Figure 2.5, Figure 2.6, and Figure 2.7 respectively. A designer was defined as an agent that specifies the structural properties of a design object. In practice, anyone who creates tangible or intangible objects, such as consumer products, processes, laws, games and graphics, is referred to as a designer [117]. A researcher was defined as somebody who performs research, independently as a principal investigator, the search for knowledge or in general any systematic investigation to establish facts. Researchers can work in academic, industrial, government, or private institutions [8]. A practitioner was defined as a person who regularly does an activity that requires skill or practice [9].

When asked *Can you consider the work you engage with to be the designing of experiences?* (Table 2.8), all 42 respondents (100%) indicated that their work engages with the designing of experiences, yet only 28 of the 42 respondents (67%) indicated that they considered themselves to be an experience designer when asked *Do you consider yourself to be an experience designer?* (Table 2.9). This disparity may be attributed in part to the unestablished definition for the term *Experience Designer*.

[8] http://en.wikipedia.org/wiki/Researcher
[9] http://www.merriam-webster.com/dictionary/practitioner

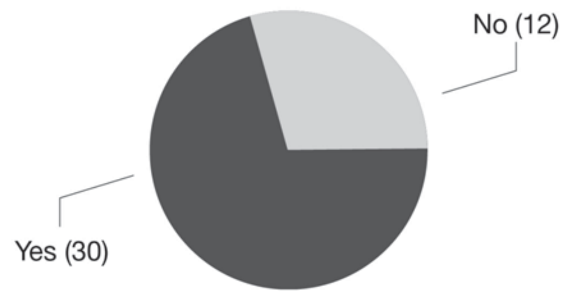

Figure 2.5: Total result of responses when asked *Do you consider yourself a designer?*

Figure 2.6: Total result of responses when asked *Do you consider yourself a researcher?*

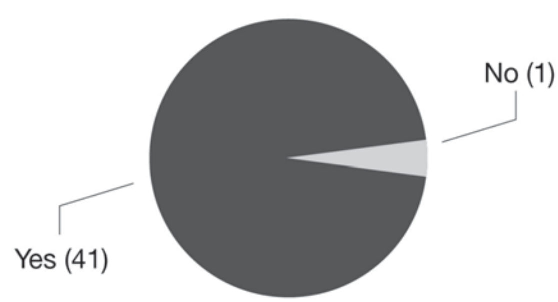

Figure 2.7: Total result of responses when asked *Do you consider yourself a practitioner?*

Figure 2.8: Total result of responses when asked *Do you consider yourself to be an experience designer?*

Figure 2.9: 100% of survey participants consider the work that they do involves Experience Design, when asked the question *Can you consider the work you engage with to be the designing of experiences?*

Also as with many multidisciplinary practitioners, the use of well-established titles that are defined by their profession could also contribute to the resistance in calling oneself an *Experience Designer*. Regardless of these consideration, the fact that 100% of all participants considered at least part of the work that they do experience designing, it can be assumed that the practice of experience design is multidisciplinary and is practiced by many practitioners across the fields of design, and science and technology.

2.1.3 Challenges of Working in Multidisciplinary Teams

Taking the results presented in the above subsection into consideration, it is explicit that experience designing requires a multidisciplinary approach. To further understand why a portable and generalised toolkit for experience designers is needed, an analysis of the challenges of working in multidisciplinary teams should be considered. In regards to the disparity of multidisciplinary learning between the workplace versus classroom, Wojahn et. al considered the challenges in regards to communicating discipline-specific concepts in a technical curriculum, and how it is inadequate considering that companies and workplace teams are increasingly becoming more and more multidisciplinary [155] when compared to the siloed and compartmentalized state of undergraduate studies. Furthermore, previous work in this area has been considered in the field of psychology [65][132]. Specifically in regards to experience design practice, no work has been done to understand these challenges. Using the data collected in the outlined survey, respondents shared their perspective when considering these challenges. The following are some of the direct quotes collected from the survey.

- Implement designing ideas to workable prototypes using technology. *Male, 30, PhD Candidate in CUTE.*

- Maintain the balance between the ultimate design and technical feasibility of the implementation. *Male, 30, Researcher at the National University of Singapore.*

- Communicate the feasibility of ideas to designers. To understand the real need of users. Users lie to you some times. *Male, 28, Assistant Professor at City University Hong Kong.*

- Communication is usually the biggest challenge, designers and developers often speak different languages, so I think it's beneficial to work across the spectrum of both roles as much as you can. *Female, 28, Previously Teaching Assistant at Keio University.*

- It is difficult to find the right resources and right person to solve the problem. The communication between different areas is not always going well. *Female, 26, Research Assistant for UX at CUTE.*

- Different priorities, different values, different languages. *Female, 35, Architect formally working at OMA, Atelier Bow Wow, now Lecturer at University of Adelaide.*

- Syncing between the teams. Finding a common language and understanding. *CEO at T.Ware.*

- Other people not being used to working across disciplines, and not being able to understand that someone might have skills outside their official job title. *Female, 30, British Music Experience Education Manager and Experience Design tutor for Artscom at Central St Martins.*

- Speaking the same language. Filling the gaps; transcending and coordinating between disciplines. Creative direction; making sure the overall experience is more than the sum of its parts. *Female, 32, Senior Designer at a design consultancy based in Singapore, formally Creative Director of Arthesia, Exhibition Designer for OMA, Senior Designer at IDEO and Designer at KesselsKramer.*

- Common language; evaluate may mean something different to a sculptor than to an HCI person. *Male, 50, Casual lecturer at university, Contract programmer and designer, PhD student, Musician, Consultant, Geek-in-Residence.*

- Passions and desired audiences are often different. *Male, 38, Assistant Professor at Aarhus School of Architecture.*

- Spending time trying to understand each other, differences in terminology, in goals, in ways of thinking. *Male, 36, University professor, teaching about HCI and supervising master's and phd research projects in information visualization.*

- Making sure that everyone is always on the same page. Having a rigid execution process, very little scope for flexibility as any deviation from the defined

Figure 2.10: Total result of responses when asked *Do you work in a multidisciplinary team?*

process affects the work of multiple members. Identifying if the approach others are following is the most optimum for the proposed solution. given the little understanding of other's domain, you always ponder if there is a better way to do their work. *Male, 22, Currently a PhD Student at NYU, previously an Analyst, Deloitte Consulting LLP.*

- Sincerely no challenges. I think a multidisciplinary team enriches the team and helps to create better results. Having different points of view and bringing into the table different experiences of the team members are all for good. *Female, 31, Senior Design Researcher at Asus.*

- Managing different points of view. Co-ordinating different outputs into one cohesive whole. Dealing with the breadth and complexity of taking on projects that require such a multidisciplinary output. *Male, 39, Formally Design Account Manager and Senior Design Consultant at Philips Design, currently Creative Director at Chemistry Pte Ltd.*

As represented in Figure 2.10, 37 of the 42 survey participants answered positively when asked *Do you work in a multidisciplinary team?* A weighted list (Figure 2.11) was generated using all survey responses pertaining to the question *What challenges do you face working in multidisciplinary teams?* at Wordle. Major terms that were

Figure 2.11: A weighted list containing the major keywords from the responses to the question "What challenges do you face working in multidisciplinary teams?" shows that the terms communication, language, process and understanding take precedence when understanding the challenges when faced with multidisciplinary teams.

shared across many of the challenges include communication, language, process and understanding, when outlining the challenges multidisciplinary teams face.

2.1.4 Design Practitioner versus Design Researcher. Is there a difference?

As stated in the above subsection, and for the purpose of this study, a Practitioner is defined as *a person who regularly does an activity that requires skill or practice*, while a Researcher is defined as *somebody who performs research, independently as a principal investigator, the search for knowledge or in general any systematic investigation to*

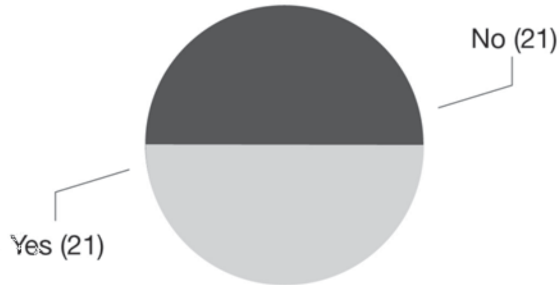

Figure 2.12: Total result of responses when asked *Do you consider the work you do academic work?*

Figure 2.13: Total result of responses when asked *Do you consider the work you do commercial work?*

establish facts. These two definitions however are not mutually exclusive as there is overlap. A researcher is in many ways also a practitioner, as the practice of specific skills are needed to conduct research. Likewise a practitioner in essence bases their practice on the theory and research one's practice is based on. This is evident when analysing the responses provided by participants in the survey presented.

Figure 2.14: Total result of responses when asked *Do you consider conducting research a fundamental part of your practice?*

Figure 2.15: Total result of responses when asked *Do you think design research is useful in a commercial setting?*

Figure 2.16: Total result of responses when asked *Do you think design practice is useful in an academic research setting?*

When asked if participants considered the work they do as academic work, exactly 50% (21 out of 42) of participants answered *Yes* (Figure 2.12). When asked if they considered their work as commercial work (Figure 2.13), 27 out of 42 participants (64%) indicated that the work they do as commercial work. When asked if they considered conducting research a fundamental part of their practice (Figure 2.14), 39 of 42 participants (93%) considered research as fundamental to their practice. This significant number indicates that research is essential to both academic and commercial practices.

Specifically in regards to design research versus design practice, 41 out of 42 participants (98%) indicated that design research is a useful component in the commercial design environment, as shown in Figure 2.15. Likewise a significant amount of respondents (39 our of 42, or 95%) considered design practice a useful component in the academic research setting, as depicted in Figure 2.16. Although an interesting if not predictable outcome, this question can be considered faulty, as most likely the answer to both questions (*Do you think design research is useful in a commercial setting?* and *Do you think design practice is useful in an academic research setting?*) may have been posed incorrectly as to coerce participants to answer positively. Yet if any insight can be extrapolated from the above results, it can be further understood that multidisciplinary teams consisting of both design practitioners and design researchers are important to both the academic and commercial environments. This is evident when looking at the results of asking participants if they worked in multidisciplinary teams, to which respondents answered *Yes* to a significant amount (37 out of 42, or 88%). Furthermore the results seem to indicate that Design Practice and Design Research come hand-in-hand, and are essential to the overall concept of design. This is further evident with the popularity of academic discourse [37] in regards to design concepts such as design thinking [10] and its derivatives [22] in the research setting [23].

2.1.5 Outlining the Differences Between Working as a Designer in an Academic Setting Versus a Commercial Setting

If it can be assumed that design researchers and design practitioners are one and the same, or at least that designers employ both traditional design tool crafts as well as research methods. Outlining the differences in working environments becomes the next question. In order to understand this better, participants of the survey were posed with the following questions: *What do you consider to be the differences between design research in an academic setting versus a commercial setting?* and *What do you consider to be the differences between design practice in an academic* *setting versus a commercial setting?*. The following are some of the responses from these two questions.

What do you consider to be the differences between design research in an academic setting versus a commercial setting?

- The biggest differences I think is for a commercialised product the most important issue is marketing, and possibility to make profit. Designers needs to consider it most, and sometimes it limits the creativity. *Male, 28, Assistant Professor at City University Hong Kong.*

- I would say research in academic settings has more chance for more open/radical ideas. I feel this is due to the less strict requirements for KPIs (key performance indicators) such as academic papers, etc. and the ability to secure more grants for more open ended grants. i.e. failure in a design research product could be another results where in a commercial setting, it could be a huge set-back for the commercial entity. This does not mean that commercial entities do not come up with new radical ideas. I would say that these entities are focused more on designing for products that are generally required to be successful. This may need these entities to focus on proper guidelines and methodologies where as the academic community has more flexibility in this regard to "explore" potential areas. *Male, 31, Research Fellow at Singapore University of Technology and Design*

- Academic setting I think is more open to experiment with new areas than commercial setting which is more focus in branding. Also most of time commercial settings are defined as event or campaign base rather than long term research or study. *Male, 30, Research Associate at CUTE.*

- Academic: With more time, design research is more extensive, with a wider spectrum of studies and more possibilities of connecting disciplines during the design processes, with no direct application to everyday design practice. Commercial: Less detailed study on the subject/product, focus is more on the end user requirements. *Female, 30, Senior Designer at M.inc.*

- The two should be connected. It should not be so different. Both should feed back into one another. *Female, 35, Architect formally working at OMA, Atelier Bow Wow, now Lecturer at University of Adelaide.*

- My opinion is that research in a commercial setting is very important in how you deliver the insights, and how designers (of all field) can make use of it. After all it's all about implementation of ideas, so if the scenario is not making sense or is not reasonable/feasible, less the value of research outcome can bring about bridging is the key. While in academic setting, it's all about exploring and making it profound. Scenarios created might not be reasonable or realistic, sometimes very blue-sky, which are fine, because the main thing is about the ideas. *Female, 29, User Experience Designer at Asus.*

- The aims and objectives. Straight academic research is typically more 'blue sky'. *Male, 64, Composer and Sound Artist.*

- The time framework are different, in a commercial setting the outcomes are expected sooner. In a commercial setting the "mistakes" or unexpected outcomes are less welcomed even when they bring more interesting data. The commercial is looking sometimes for specific outcomes, while the academic can be more experimental. *Female, 36, Founder of Xuna in partnership with Interexpo Co. Ltd.*

- Time line is much shorter for commercial setting. Need to be much more focused on delivering value that can be monetized. *CEO at T.Ware.*

- I'm not sure that there is one, however I have come across a difference between the ways research is used in a commercial vs. audience focused setting.

  A large music venue that I happen to know has a data management system which they use to handle the emails they receive to their customer services team. This system is set up to enable them to process the emails they receive more quickly, and to monitor the flow of information so they can see which staff member has dealt with the most complaints the quickest.

  It is not however capable on reporting on the type of contact they get (complaints, feedback, issues, lost property, etc.) or the general levels of customer satisfaction - a conversation is flagged as resolved when the customer stops replying.

  The data generated is used to design a better system from the point of view of the company - not the customer. They use the data to design a 'better' system for answering emails, not a better system for dealing with - and ultimately eliminating - customer issues. *Female, 30, British Music Experience Education Manager and Experience Design tutor for Artscom at Central St Martins.*

- Speed... time constraints in a commercial setting and a fixed production date means less time to explore, research. The need for a very defined research focus. *Female, 26, Designer at T.Ware.*

- In an academic setting, design research focuses on gathering data and finding patterns in it where as in a commercial setting it focuses more on gathering insights through observations. *Male, 30, Lead UX Designer at Honeywell Technology Solutions Lab.*

- Academic outcomes are for dissemination and platforms of communication, commercial design research is focused on developing a brand or business. *Male, 38, Assistant Professor at Aarhus School of Architecture.*

- Design research in an academic setting will start from a question or idea set by an individual, while commercial settings normally come from solving problems or requests from client and stakeholders. *Female, 31, Formally Multimedia Designer at mig33 Pte Ltd and Web Designer at Converse Singapore.*

- Academic: less of a need to be practical, can be longer term / more forward looking and less constrained. *Male, 36, University professor, teaching about HCI and supervising master's and phd research projects in information visualization.*

- In commercial setting, the end result is more refined, less buggy and easily replicable. In academic setting, the novelty of a design is given priority. However, in commercial setting, the feasibility of a design (and if it can be pushed to market) and ease to use of the final outcome are focused upon. *Male, 22, Currently a PhD Student at NYU, previously an Analyst, Deloitte Consulting LLP.*

- Academic settings look for novelty while commercial setting looks for commercial success. That's the main difference. *Male, Unknown Age, Assistant Professor in HCI at the National University of Singapore.*

From analysing the results a number of insights can be obtained. First, a majority of survey participants believe that the outcome focus for design research in an academic versus commercial setting is that of novelty versus commercial viability. Design research conducted in the academic setting looks to develop novel research outcomes that may not be feasible or even usable by everyday users. Commercial applications of design research look to improving the final product or user experience, in relation to the profitability of said product or user experience, however. Another interesting outcome of the survey question includes the the constraint of time. Several of the respondents thought that design research in the academic setting was not hindered by constraints such as market cycles. This wider allocation of time for academic design researchers allowed them more freedom for exploratory research. On the other hand, design researchers working in the commercial space were focused on very strict deadlines in alignment with the brief set out by the client. Where some respondents did agree was that design research in both the academic and commercial environments is conducted to obtain insight instead of hard data.

What do you consider to be the differences between design practice in an academic setting versus a commercial setting?

- I think time is a big factor between working in academia versus commercial, so far. Another is probably your audience. In academia, you communicate to other academics or specialists of the given field. In the commercial setting of the daily iPad-based newspaper, you are (speaking to a) very general public (even more so than versus a news website, where there is somewhat more fluidity in terms of traffic). *Male, 33, Digital Journalist and Developer, La Presse Newspaper.*

- Academic design practice had endless possibilities. It varies and is more flexible, depending on the research and methodology used for design processes. Commercial design practice solely depends on what the clients need, with external considerations such as budget, guidelines, time, etc. *Female, 30, Senior Designer at M.inc.*

- Design practice in commercial setting has more aspects to consider. Take industrial design as an example, things like colour and materials choose, competitors, cost related issue are there to give you headache, also there are things to do with marketing, customer acceptance etc. In an academic setting, excuse me if I don't know much, design practice is more like a prototype - as long as it works. Of course it still can be great, but somehow it's not going to be sold in the shop, there are relative fewer issues to consider. I don't doubt that design is not necessary in academic setting, especially when it comes to testing or publish/promote the ideas, good design solution is likely to make the idea more convincing. *Female, 29, User Experience Designer at Asus.*

- I think in a academic setting design is used to test assumptions and the final design can be a tool to get to know something, the tool cannot be used to be sold or used in real situations for example. I think in a commercial setting, the product should be finished and to be monetized. *Female, 26, Freelance Interaction Designer, formally Interaction Designer at IDEO.*

- The outcome or aim is different. While both would be to improve the products/services/experiences on offer, an academic setting would be focused on enriching the experience for the user, while the commercial setting's main aim would be to create more value for the business itself. *Female, 30, British Music Experience Education Manager and Experience Design tutor for Artscom at Central St Martins.*

- It all depends on what are you creating and to what level? Design practice could be the same in both settings. Academics build prototypes to prove their findings/inventions where as in a commercial setting, products are built which can be used in daily life. *Male, 30, Lead UX Designer at Honeywell Technology Solutions Lab.*

- There's very little difference if the research question is relevant. Controlling for variables is probably the biggest difference. *Female, 47, Freelance Web Usability Specialist and Technical Writer, formally Assistant Professor of Business &*

Technical Communication at West Chester University of PA, Associate, Professor of Technical Communication at the University of North Texas, Visiting Instructor of Communication at Western Kentucky University.

- Academic setting: the people still following order and formally discipline. Commercial setting: people usually work in a more disorderly way and tend to forget some steps in the investigation. *Female, 26, Master Student at the Catholic University of Valencia.*

- Design practice in an academic is setting more like Activism for ethical purpose, making an effort to enhance society. A commercial setting has the aim to activate economics to enrich the target society. *Male, 35, PhD Candidate at Central Saint Martins.*

- The academic setting allows for radical experimentation while the commercial one might not, even though sometimes it does. There is less money and more politics in academy then in commercial practice. commercial settings can be more canonical, less exposed to alternative thinking then academic ones. *Female, 33, Co-director of 72 Hour Urban Action and Independent Curator.*

Reading the responses reveals that the differences between working as a designer in an academic setting versus a commercial setting focus on overall aim (creating social versus economic value), outcome (investigating a theory through prototyping versus developing a product for mass use), time (longterm exploration opposed to time constraints due to client needs), and flexibility (failure in an academic setting is useful and acceptable whereas in a commercial setting it could mean the loss of revenue). However there were some similarities which included the focus on the user to inform the design process and direct research, as well as the actual method of practice, as many believed that the same tools and methods were employed, although to differing ends.

There were a couple issues with the above two questions. From analysis of the responses, it seemed that the two questions posed (*What do you consider to be the differences between design research in an academic setting versus a commercial setting?* and *What do you consider to be the differences between design practice in an academic setting versus a commercial setting?*) were too similar for some participants to differentiate. This may be due to the idea that design practice and design research is used by all designers, regardless of work setting. However this confusion may further indicate that designers are both practitioners and researchers, as the act of designing in both an academic and commercial setting employ similar methods. Some of these tools and their uses expressed by participants are offered in the following subsection.

2.1.6 What Tools are Employed and How are they Used?

To further understand the similarities of design practitioners and design researchers, the survey posed two questions in order to understand the tools and methods that are employed by designers, as well as understand how they use them. The questions that appeared on the survey to explore this were *What methods and tools do you use for your work?* and *Which order do you use each tool or method? Please tell us how one method or tool informs the next.*

What methods and tools do you use for your work?

A weighted list was generated using all survey responses pertaining to the question *What methods and tools do you use for your work?* at Wordle, as illustrated in Figure 2.17. Major terms for the methods and tools employed include brainstorming, ethnography, interviews, mapping, prototyping and sketching. Others that were widely used include participatory, sketching, usability, tinkering, hacking, iterative, shadowing, iterative, and journey.

Figure 2.17: A weighted list containing the major keywords from the responses to the question "What methods and tools do you use for your work?" shows that the terms communication, language, process and understanding take precedence when understanding the challenges when faced with multidisciplinary teams.

This question posed may have been far too open ended, as the terms offered by participants seem general and non-specific in regards to concrete methods and tools. Nevertheless it can been seen that similar concepts for the general tools used by all participants regardless of practice or background were shared to a high degree. Further evidence for this can be found in a following Appendix chapter, in the form of the raw data responses. This also further supports the view that design-centric tools are increasingly becoming employed by practitioners and researchers from areas other then design. These general tool and method terms might have been used as responses due to the multidisciplinary nature of the teams some participants operate in. If this is indeed the case, then a general vernacular that is easily understood amongst differing practitioners and researchers is required, therefore the generality of the above terms offered could be such a vernacular for all members of a multidisciplinary team to communicate and work with one another.

Which order do you use each tool or method? Please tell us how one method or tool informs the next.

The goal of this question was to understand if a common workflow process could be prescribed to designers working in both the academic and commercial fields. This informed the development and purpose of the toolkit proposed in this dissertation. The usage of methods and tools employed in the work process cycle of participants varied to a minimal degree. Overall, similar tools were used at similar stages of a process with little deviation. A sample of some of the responses to the question are as follows.

Female, 28, Currently Unemployed, previously Digital Designer.

1. Research into technologies, competitors and design requirements, discussion with client on their purpose and previous experiences

2. Gathering tech tools and registrations (domains, hosting, etc.)

3. Paper design, wireframes, consult with client (navigation, content)

4. Build and customise (wordpress, html, css, templates, fonts, colours)

5. In-house testing

6. Customer feedback, redesign or signoff

7. Go live

8. Handover or continue management

9. Continuing content and community engagement

Male, 31, Research Fellow at Singapore University of Technology and Design

1. Idea generation (could be from any thing : improving existing, notice differences, brainstorming, etc)
2. Research for existing technologies (try to identify technologies/processes related to the idea, this could lead into identifying ways to implement, and also identify which features could be added or removed, or simply stop if a closely similar product/tech exists)
3. Prototype (make an initial version of the product that is presentable to a user)
4. Present to users for evaluations (get the users' feedback, ideas, potential new application areas, evaluate for usability or other metrics)
5. Based on feedback tinker/hack or create new prototype
6. Iterate this process

Female, 26, Research Assistant at CUTE

1. Ethnographic study, field work
2. Focus group
3. Experiment design
4. Statistical analyzation
5. User-centered design

Female, 32, PhD Scholar at CUTE

1. Survey (previous works) to find the gaps and problems

2. Participatory design to empathise with user and figure out the form factors

3. Tinkering and iterative prototyping to facilitate brainstorming and then again go back to design

Female, 32, Senior Designer at a design consultancy based in Singapore, formally Creative Director of Arthesia, Exhibition Designer for OMA, Senior Designer at IDEO and Designer at KesselsKramer.

1. Discover - research

2. Define - looking for patterns and insights, coming up with opportunities to improve and innovate

3. Develop - coming up with design direction, concept design and final designs in an iterative process through repeat prototyping and testing

4. Deliver - final design and production

Male, 30, Lead UX Designer at Honeywell Technology Solutions Lab.

1. User Research

2. Problem Framing

3. Concept Ideation

4. Interaction Design

5. Prototyping

6. Usability Testing

Female, 47, Freelance Web Usability Specialist and Technical Writer, formally Assistant Professor of Business & Technical Communication at West Chester University of PA, Associate, Professor of Technical Communication at the University of North Texas, Visiting Instructor of Communication at Western Kentucky University.

1. Identify a phenomenon
2. Research the academic literature
3. Formulate a research question
4. Identify appropriate publication venues
5. Design the study
6. Submit the study to the IRB
7. Wait
8. Recruit participants
9. Run the study
10. Analyze the findings
11. Write the journal article
12. Edit the article
13. Submit the article
14. Wait for reviews
15. Revise and resubmit

Male, Unknown Age, Assistant Professor in HCI at the National University of Singapore.

1. Research seminars
2. Contextual inquiry
3. Brainstorming

4. Rapid prototyping
5. Interactive design
6. User evaluation

Overall, survey participants provided clear and concise process flows but did not discuss the extent that each step influenced the next. This may have been a problem in the length and complexity of the question. A possible solution to this would have been to use a problem/scenario-based question and have participants explain the process of solving it. Still, an atypical workflow can be derived from the answers.

The first step that is shared across a majority of survey participants is an identification and framing period in order to understand the problem for which the design solution is attempting to solve. The second step that is similar across survey participants is an ideation or conceptualisation period, in order to brainstorm on possible solutions. Next, ethnographic and user-centric study is conducted to characterise and better serve the user a design is serving. After understanding the user, a period of prototyping and implementation occurs. Once a prototype is created, it is brought back to the client or user for evaluation and testing, the results of which are used to inform new versions of the implementation. This cycle is repeated however necessary, or however long one has during the development process.

Process steps seem to be very similar for people working in both the commercial and academic environment. Even though there was some variation in regards to the steps and processes, the similarities allow for the outlining of a common workflow that can be used for the purpose of the proposed toolkit presented in this dissertation. Figure 2.18 depicts this atypical workflow.

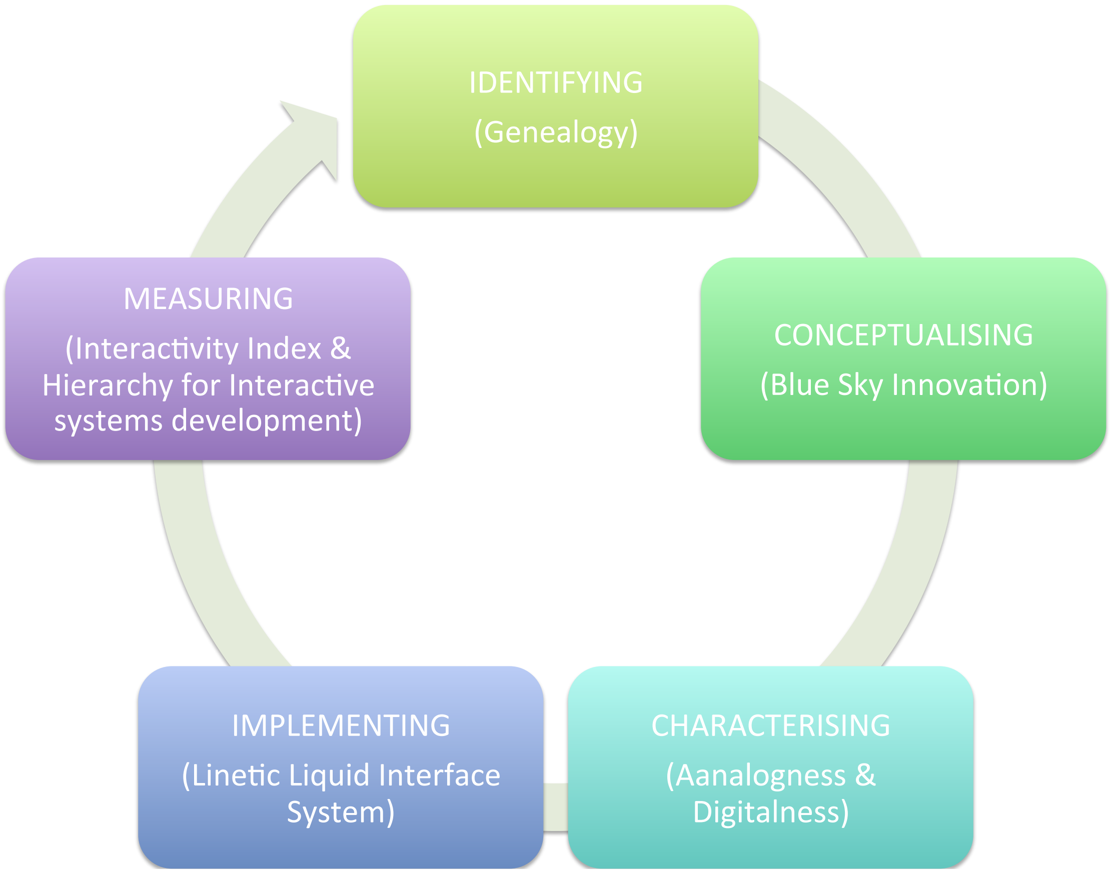

Figure 2.18: An atypical workflow based on the responses from the survey presented in this chapter

2.1.7 The Perceived Importance of Research, Prototyping and Testing

Likert-styled questions were asked by the survey in order to get a feeling of the importance of research, prototyping and testing within an experience designer's workflow. The six questions asked were subdivided into pairs. Each contained the statement *Please state the importance of* (research or prototyping or testing) *when participating in a project workflow cycle*, and were matched with the statement *Please state how much time you dedicate to* (research or prototyping or testing) *during an entire project or workflow cycle*. This was done to gain insight into which were perceived

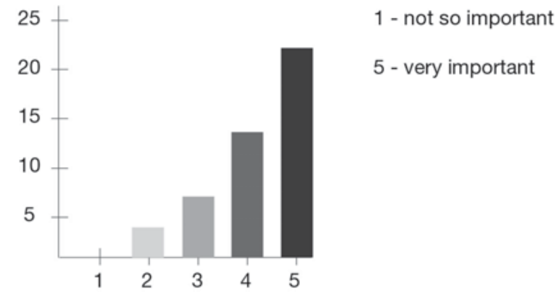

Figure 2.19: Total result of responses when asked *Please state the importance of research when participating in a project.*

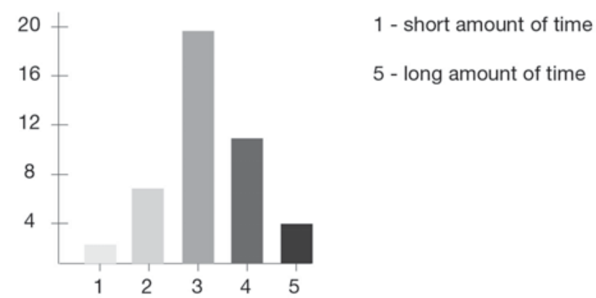

Figure 2.20: Total result of responses when asked *Please state how much time you dedicate to research during an entire project or workflow cycle.*

important versus how much time during a workflow cycle was actually dedicated to each task. The results are as follows for each question are as follows.

From looking at the results a number of insights can be derived. First, even if *research* for a project is perceived as *very important* (23 respondents or 55% of all responses depicted in Figure 2.19), 19 (45%) of respondents only dedicated a moderate

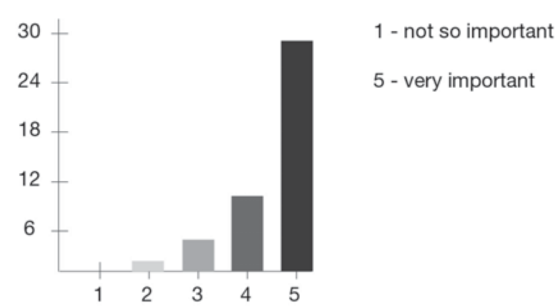

Figure 2.21: Total result of responses when asked *Please state the importance of prototyping when participating in a project workflow cycle.*

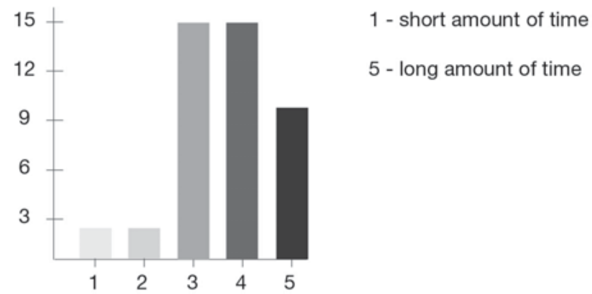

Figure 2.22: Total result of responses when asked *Please state how much time you dedicate to prototyping during an entire project or workflow cycle.*

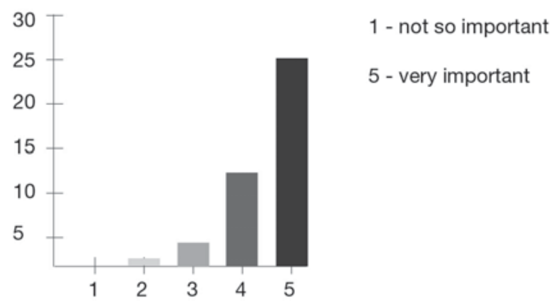

Figure 2.23: Total result of responses when asked *Please state the importance of testing when participating in a project workflow cycle.*

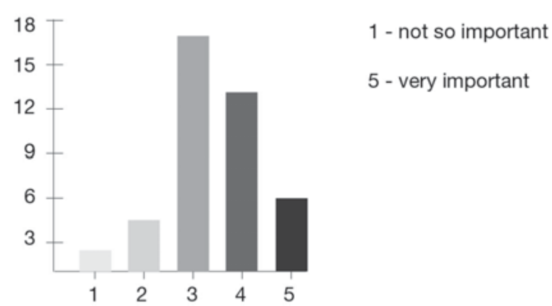

Figure 2.24: Total result of responses when asked *Please state how much time you dedicate to testing during an entire project or workflow cycle.*

amount of time towards the task (Figure 2.20). In regards to *prototyping*, a majority of 29 respondents (69%) believed that prototyping was very important to their work (Figure 2.21), and because of this, a total of 57% of responses indicated that they spend a moderate to long amount of time dedicated to prototyping (Figure 2.22). In regards to *testing*, 26 respondents (62%) indicated that testing was was very important to their workflow (Figure 2.23), yet 17 of the respondents (40%) indicated that time for testing was only moderately applied (Figure 2.24). These results may indicate that from the three tasks, research and prototyping take a more important role in the workflow process, with testing also important if there is enough time to do so. Considerations for work environment (academic versus commercial) might also be a factor, as participants who are working in the commercial field may have different amounts of time to execute each task. It can also be assumed that research tasks are more focused in the academic settings, especially in prototyping in order to qualify a theory or hypothesis. This is indicated by the responses in the previous subsections of this survey study.

2.1.8 Discussion

In summery, several insights as to the working nature of design researchers versus design practitioners was uncovered. *Experience design* seems to be practiced by a multiplicity of fields, focusing on the design and technology practices. Even if one does not label oneself as an experience designer, a full 100% of all participants, regardless of professional background or education, considered part of the work that they do to include the designing of experiences. This population includes graduate students, professional designers, artists, consultants, researchers and university professors.

Additionally, a definition of the term *Experience Design* could be synthesised from the survey responses. Using the responses and weighted list presented above, this definition would look to include the designing of products and processes that are created in service of the user's experience. WIth this apparent, Aarts and Stefano's definition of *Experience Design* as the practice of designing products, processes, services, events, and environments with a focus placed on the quality of the user experience and culturally relevant solutions [1] remains relevant and can be used as a contingent definition for the purpose of this dissertation.

The differences, similarities and challenges for experience designers working in the commercial and academic environments, as well as the challenges of working in multidisciplinary teams can also be gleamed from the responses offered in the survey.

In regards to the differences between experience designers working in the commercial versus academic fields, value for the profitability of the company compared to scholastic value in novelty, and publishing or decimating knowledge, seems to be the key differences in regards to aims. Outcomes also differ, in the sense that commercial works need to be robust and applicable to wide markets, whereas applications developed in the academic environment usually remains in prototype form in order to test or prove hypotheses or theories. Time span seems to loosely differ as well to some extent. In the commercial setting, allocation of time is constrained by the needs of a client, whereas in the academic field, longterm exploration and enquiry are encouraged. Finally in regards to flexibility, academic practice allows for room for failure, as it may provide valuable knowledge to a body of knowledge. In the commercial environment, failure can have critical implications such as loss of revenue. Failure in relation to the survivability of a company is often mitigated instead of accepted, such as in the academic work environment.

Similarities between experience designers working in the commercial versus academic fields focus on the tools and methods that are used, especially in the task execution order in workflow processes. In general, workflows across both environments include an identification and framing period so as to understand the current state of the problem being addressed, and ideation or conceptualisation (brainstorming) period to conceive possible solutions, user-centric study including methods from ethnography in order to contextualise and characterise the user a solution is being developed for, as well as periods of time for implementation prototyping, and then testing or measuring the effect of such prototypes on the target user or client. This distilled workflow cycle can be used as a map for the toolkit proposed in this dissertation.

From the responses provided by participants and through analysis using a weighted list, challenges when working across multidisciplinary teams include communication, language, process and understanding. From participants with an academic background, one professor from Honk Kong stated that communicating the feasibility of ideas to designers was a challenge. Another professor from Aarhus discussed the differing audiences between members of a multidisciplinary practice. Finally another HCI professor thought that spending time trying to understand members of a multidisciplinary team takes effort. This is again due to the goals of each member, as well as the terminology that is used in varying fields.

In regards to responses from survey participants working in the commercial field, a creative director formally from Philips Design stated that managing different points of view and co-ordinating the different outputs into one cohesive whole was a challenge. Another senior designer, formally working at IDEO and OMA mentioned that transcending and coordinating disciplines in order to develop an overall experience that is more then the sum of its parts, was a main challenge. Overall, the challenges perceived by those working in both a research-based (academia) and commercial-based setting were more similar then different. This would support the assumption that a toolkit could be developed that is able to be used by both researchers and practitioners in the academic and commercial environments.

Finally in regards to the perceived importance of research, prototyping and testing, versus the amount of time allocated to the pursuit of each, some insights can be outlined. Generally, in both the academic and commercial fields, all three tasks are considered to be important to the process of developing solutions for users. Yet with the current tools employed, the amount of time dedicated to each step seems moderate at best. This may be due to several factors including access to resources or methods that allow for rapid execution during tight deadlines. With this in mind, a toolkit that collected easy-to-use and resource efficient methods could be valuable, especially in the commercial field, where time is the most rare of resources.

Several areas where the survey could be improved include the use of a scenario-based problem in order to better understand the workflow and problem-solving process between the various types of survey participants. Beyond wording of the questions as well as sample size to better reflect the target population, a more exhaustive list of questions, especially in the Likert-style could provide a means for quantitative data results.

Chapter 3

Related Work

The research presented regarding identifying, conceptualising, categorising, measuring and implementing interactive experiences is multidisciplinary in nature. Not only was a methodology developed to identify the nature of the relationship between user and system, conceptualise new interactive works, characterise the nature of interactivity as well as measure said interactive experience, but a prototype system was also developed using these methodologies. This means that the related works are sourced from both a practical and theoretical perspective. Still, the related works in regards to the practical implementation of the Linetic system is somewhat out of scope in regards to this dissertation, therefore related works for Linetic are contained in the *Implementing: The Linetic Liquid Interface System* chapter, separately.

The theoretical section of this chapter first looks towards surveying writings focusing on an embodiment perspective in relation with interactive systems and experiences. This was made in reflection of *Analogness* and *Digitalness*. In the subsection following the survey on embodiment, this dissertation will discuss the limitations and possible detrimental effects of usability on HCI as an argument for practice-based research in the context of the practicing experience designer. Finally in the last subsection the current state of HCI toolkits is discussed.

3.1 On Embodiment

There is no widespread acceptance regarding a universal definition on immersion and embodiment, therefore it is important before moving forward to place them into context. As this section partially concentrates on human-computer interactions with a special emphasis on their embodied potentialities, embodiment will be referring to a state where one has the ability to interact with a system through an interface, as well as receive and cause stimuli and experiences within a given space. This section will explore the notions of disembodiment and the Cartesian split as well as issues of phenomenology as proposed and discussed by Descartes, Merleau-Ponty and Mark Hansen. The phenomenological theories will then be applied in creating a distinction between the interactions of a user with a digital-like and an analog-like system.

The philosopher René Descartes suggested the idea of disembodiment in the 17th century. In his unfinished treatise *The Description of the Human Body*, Descartes describes the human body as a machine, where heat from the heart causes all the movement in the body. Veins, just like pipes, carry blood from all parts of the body towards the heart, where it serves as nourishment for the heat that is there. He believed that the most agitated and lively part of the blood would be taken to the brain where it would compose a subtle wind, called the animal spirit or the soul, that enabled the brain to experience, think and imagine [118]. The soul, according to Descartes, is in fact a separate nonmaterial entity that exists inside and controls the body. This idea had been proposed also by Plato centuries before who believed that the body is from the material world whereas the soul is from the world of ideas, united temporarily with the body and separated at death when it would return to the world of *Forms*. This dichotomy of the body and soul - commonly referred to as dualism or the Cartesian split - serves as the basis for modern ideas about disembodiment, inhabitation of virtual avatars and transfer of consciousness from one body to another.

Jacquelyn Ford Morie, looking at immersion from a phenomenological point of view, argues in her paper *Performing in (Virtual) Spaces: Embodiment and Being in Virtual Environments* that *VEs engage the body as kinesthetic input via the specialised interface devices that not only permit but require bodily actions to be performed sensorially, kinesthetically and proprioceptively - within a full 3d spatial yet virtual construct* [106]. She goes on to mention that since the VR equipment mediates our perception, we must try and understand what constitutes a mediated environment.

The French phenomenological philosopher Maurice Merleau-Ponty on the other hand, views the phenomenal body as our primary access to our reality. Even though there are several approaches to phenomenology, Merleau-Ponty views the individual and the world not as part of a whole but rather as separate entities subjected to the phenomenon of the individual. Hansen, in his book *Bodies in Code* celebrates and expands this idea to the domain of new media art [55]. He argues that technologies can change or enhance our sensory experiences consequently affecting our view of embodiment. Wanting to move away from what he calls the *clichs of disembodied transcendence*, Hansen envisions a world with a fluid interpenetration of the virtual and the physical realm [55]. Deriving his theories from Merleau-Ponty′s notion of *reversibility* and the idea that the body has an ability of inverse sensorial duality (for example, it can see and can be seen), the main focus of Hansen′s book is how vision needs to be combined with touch in order to shorten the gap between ocularcentrism[1] and a body′s inherent simultaneous multi-sensations.

Going a step further, Hansen argues *Motor activity* - not representationalist verisimilitude[2] holds the key to fluid and functional crossing between virtual and physical realms. According to Hansen the success of generating compelling virtual experiences comes not from representational aesthetics but rather by simulating tac-

[1]The privileging of vision over the other senses

[2]*Verisimilitude* is a philosophical or theoretical concept that distinguishes truth and falsity of assertions or hypotheses. The problem of verisimilitude is the problem of articulating what it takes for one false theory to be closer to the truth than another false theory.

tile, proprioceptive and kinesthetic sense modalities. Expanding on a theme addressed in his previous book *New Philosophy for New Media*, Hansen couples the sense of reality with touch and the perception of spatial depth and argues that by including bodily movement the formula has enough elements to *synthesise* the other senses; therefore perception is transformed into experience. He calls this notion *Mixed Reality* and defines it as *The eschewal of representationalism and embrace of a functional perspective rooted in perceptuo-motor activity* [55].

In HCI, the controls of an analog-like interface can be directly integrated or expanded into a perceptuo-motor activity, as there is no technological mediation between the interface and the system. Digital-like interfaces on the other hand are not a direct result of *the organism within* but rather on the representation of the action as mediated by the technology (what Merleau-Ponty refers to as the *body image*).

Hansen, in his first chapter in *Bodies in Code* defines Merleau-Ponty′s body image and body schema as *...The body image characterises and is generated from a primary visual apprehension of the body as an external object, the body schema emerges from what, with autopoietic theory, we have called the operational perspective of the embodied organism* [55]. Merleau-Ponty offers an account of the body schema as *a flexible, plastic, systemic form of distributed agency encompassing what takes place within the boundaries of the body proper (the skin) as well as the entirety of the spatiality of embodied motility.* In other words the body image refers to how the body is represented whereas the body schema refers to the organism within, which is caused by movement and subsequently causes it [103]. As Hanson phrases it: *Because it is responsible for linking proto-sensory bodily sense (proprioception) with perception and motility the body schema is a source of embodied potential* [55].

Discussing along the same lines, Brian Massumi in his book *Parables for the Virtual* argues that the digital realm has potentiality but what really produces the possibilities (which he calls inventions) is the analog. *Whatever inventiveness comes* *about, it is a result not of coding itself but of its detour into the analog. The processing may be digital - but the analog is the process. The virtuality involved, and any new possibility that may arise, is entirely bound up with the potentialising relay. It is not contained in the code* [100].

As this dissertation is partially concerned with the user experience and the embodied interaction between a user and a system, a clear differentiation can be noted between a user interacting with the body schema and one that is not. When an action comes from *within one′s organism*, as a direct continuation of an embodiment in space, it becomes intuitive and analogous to the data it represents. When the interface is of a digital-like form, the action does not flow naturally but rather is broken down and rebuilt in a discrete manner dependent on the rules specified by the mediating technology, resulting into a dichotomy of the embodied potential and the intended result.

3.2 Regarding Insight in the Context of Design Research

There are several prevalent theories in regards to the phenomenon of insight as a product of problem solving. This includes the Dual Process [91] theory, the Three-process [28] theory, and the Four-stage [54] method.

Within the Dual Process theory, two systems are outlined when used to solve a problem. One system is that of logical and analytical process. This process is based on reason. The second system involves intuition and experience-based processes. According to Lin et. al, the second process is the more influential of the two, in regards to the system one uses to solve a problem.

The Three-process theory places emphasis on the intelligence, and the role it plays on problem solving. Specifically in regards to insight, three different processes are employed. This includes selective encoding (the process of focusing attention on ideas relevant to a solution, while ignoring features that are irrelevant), selective combination (the process of combining the information previously deemed relevant), and selective comparison (the use of past experience with problems and solutions that are applicable to the current problem and solution). According to Davidson and Sternberg, these three processes involve the application of intelligence.

Finally, Hadamar's Four-stage model offers four stages to problem solving. In the first stage, the individual prepares to solve a problem. Next, the individual uses trial-and-error, etc. to incubate on the problem. The third stage is where insight occurs, and the solution is illuminated. In the fourth and final stage, the individual employs selective comparison to refer to past experiences of problems and solutions to see if any are applicable to the current problem and solution.

The term *insight* is defined by the Oxford English Dictionary as the capacity to gain an accurate and deep understanding of someone or something [3]. In regards to insight within design research context, Barab and Squire state that *the goal of design-based research is to lay open and problematize the completed design and resultant implementation in a way that provides insight into the local dynamics* [6].

Yet design research can be used even before a completed design exists. Beyond the definition provided by Barab and Squire, design research also provides an opportunity during the development process to gleam insight in order to direct the course of designing a system or experience. Two design research consultants from the Chemistry [4] design consultancy speak about insight from design research:

> Research is an essential part of our projects. Our focus is to augment the prevalence of hard quantitative data that our clients often already have with more empathic and behavioural insights. The latter allows our clients to see their customers as people rather than data sets. This

[3] http://oxforddictionaries.com/definition/english/insight
[4] http://chemistryteam.com/

is to understand and cluster them in terms of behavioural preferences and attitudes rather than demographics and numeric attributes. This approach allows us to bring a richer and more tangible perspective to our creative workshops, providing a fresh point of view for practically all our clients to date for them, in order to generate new and compelling solutions that would better meet their customers' needs. *Bassam Jabry, Creative Director at Chemistry.*

The research phase is a crucial part of our design process. The methods we apply could be classified as ethnographic or qualitative in nature. Although at times it might be difficult to initially convey the importance and impact of ethnographic research to our clients, time and time again the quality of the insights gathered are able to convince them. Instead of targeting large numbers of people through surveys or focus groups, our research aims at a smaller number of participants, but in richer and more engaging formats. Next to face-to-face, in-depth interviews, that feel more like open conversations rather than strict data gatherings, we use observations, or shadowing of our participants to get a deeper understanding of their life. This form of research allows us to uncover insights around what motivates our users, their worries, aspirations and the thought processes behind their actions, or non-actions. By using different research tools in parallel we can uncover new aspects of their world. Working and engaging with them directly in the environment they live and work in helps us as designers, the tools to uncover pain points and opportunity areas in order to come up with improvements and innovative new solutions for the problems at hand. *Karin Aue, Senior Design Consultant at Chemistry.*

From the above quotations, it is apparent that the purpose of insight, at least within the context of design research, aims for intuition as an outcome. The targets of such solutions developed from these insights seemed to not only be aimed at very specific clients, but also the users that these clients target, such as a market, user-base or community. The value of strict data collection comes secondary to understanding the behaviours, motivations and aspirations of these markets, user-bases and communities, and thus through transmutation, also the behaviours, motivations and aspirations of the organisations that serve them. These aspects are also increasingly important to academic research, specifically within the HCI field, as the research conducted in organisations such as MIT Media Lab and CUTE look to applications and prototyping to deliver solutions aimed at society. As such, there has been an increasing amount of design research techniques used in such research institutes. The value of this type of research method within the context of HCI has been discussed, most notably by Greenberg and Buxton [52]. A discussion of this is expanded in the following section.

3.3 On Usability Evaluation

Saul Greenberg and Bill Buxton presented a paper at ACM CHI 2008 regarding the possibly harmful effects of usability evaluation [52]. They argue that although useful, when employed *by rule* as opposed to *by thought*, usability testing can, among other things, stifle innovation, mute creative ideas and quash inspired vision. They identify that any type of evaluation methodology should be used appropriately, with consideration to an actual problem or research question and go so far as to suggest that evaluation is often not even needed for some of the works produced within the CHI community.

This is not to say that user evaluation is completely useless. On the contrary, Dix et al. describes evaluation as a good way to *asses our designs and test our systems to ensure that they actually behave as we expect and meet the requirements of the* *user* [32]. The issue that arises is the appropriateness for evaluation in regards to the context of the research.

Commonly practiced usability evaluation methods are numerous. Some of the more popular techniques include user observation in laboratory settings, controlled user studies, and various inspection techniques [32] [109] [7]. The purpose of employing such techniques are varied depending on context. Identifying usability bugs is often the goal of practitioners evaluating products and services. It is often the job of developers to take into consideration these bugs and develop fixes appropriately. This is often cited as part of iterative development [11].

Acceptance testing also relies heavily on usability evaluation. This often entails qualitatively measuring a user's successful performance according to various criteria, including measurable parameters such as satisfaction, error rate and time to complete task. In terms of deciding on purchasing one product versus another, usability testing can determine which product is better at certain functions compared to another.

Specifically in the field of HCI research from a scholastic perspective, usability is often employed to evaluate novel design concepts, often in the prototype stage of development, in order to validate design choices in terms of human performance. Most often in comparison to other prototypical systems, researchers hope to show that their users achieve a stated goal (e.g. task completion, performance measures) to display that their tasks and processes are improved when using the prescribed system or method.

Clearly displayed in far too numerous studies of implementation within HCI, researchers use usability to validate their work. Greenberg and Buxton ultimately call for the HCI community to embrace and be open to other, non-empirical methods [52]. This dissertation hopes to provide the HCI community with some viable alternatives to validating their work.

3.4 On Toolkits in HCI

There are an increasing amount of toolkits at the disposal to researchers and practitioners interested in UxD and HCI. At the time of writing, Stanton et al. identified more then 200 human factor methods and tools in their book *Human Factors Methods: A Practical Guide for Engineering and Design* [131].

Most toolkits employed by HCI researchers and experience design practitioners focus mainly on deriving information from the user [56]. Even so, there has been an increasing amount of attention that focuses beyond simply incorporating user information into the development process, but also looks towards including the user in a transdisciplinary, co-creative and participatory fashion [122], in order to include affordances from the intended users of these interactive experiences.

The increasing amount of tools available to the interactivity researcher and practitioner is also, unfortunately, becoming more and more complex, so far that they become exclusive of large demographies that would hope to employ them, such as educators, students and professional practitioners, as they are either out of reach due to the specialised and specific skills needed to use them, and/or are too costly both in time and resources to practically deploy. Another critical observation is that due to their complexity, the users of such methods and toolkits do not fully understand which tools to select and when they are most appropriate [141], leading to the slow adoption of new tools [51]. This misuse of tools leads to poor collection of data, leading to faulty results for common tools used in usability tests [52] and focus groups [108].

Of the multitude of toolkits available to the experience designer and HCI developer, some of the more popular ones includes IDEO′s *Human Centered Design*

Toolkit[5], the *Human Centered ICT Toolkit* from Rotterdam University[6], and the *Methods Table* from Usability.gov[7]. An excellent synopsis of the more popular methods and toolkits in existence was presented in [141] and is the bases of the following analysis.

3.4.1 IDEO's Human-Centered Design Toolkit

IDEO's Human Centred Design Toolkit was specifically adapted for social enterprises and NGOs working with impoverished communities around the world. It was developed in collaboration with International Development Enterprises, the International Center for Research on Women, and Heifer International.

In its latest incarnation, it exists as a book that is organised into three section. These sections are called *phases* and consists of the *Hear* phase, *Create* phase and *Deliver* phase, collectively known as *HCD*. Its aim is to connect NGOs with the people they are helping. Descriptions of how the toolkit can help is illustrated with scenarios in the introduction section. The actual toolkit is then presented, which focuses on process and application.

Each tool is then organised into descriptive sections for each phase and tool. *Goals*, *outputs* and *theory* are discussed in relation to each phase of the HCD, with descriptive steps for each actionable tool. In all there are 16 tools and a total of 37 steps described in regards to their use.

Even though much emphasis has been placed on process, there is a lack of academic reference throughout the book. As the target audience is arguably less concerned with scholastic validation and more with process and outcome, this may not be an issue for most. The toolkit proposed in this dissertation is targeted at a different user-base,

[5] IDEO's Human Centered Design Toolkit (http://www.ideo.com/work/human-centered-design-toolkit/

[6] Human Centered ICT Toolkit, University of Rotterdam (http://project.cmd.hro.nl/cmi/hci/toolkit/)

[7] Usability.gov Methods Table (http://www.usabilitynet.org/tools/methods.htm)

which is the experience design researcher and practitioner, and is therefore grounded in theory that supports the development of experiences. As the toolkit proposed in this dissertation aims to be easy to use and resource efficient in order to fit into the already busy process of experience designers working especially in the commercial fields, the steps to use each of the tools described later in this dissertation have a minimal amount of steps, and includes tools that are specifically for use in the designing of experiences.

3.4.2 Rotterdam University's ICT Toolkit

Rotterdam University's ICT Toolkit is self-described as a *toolkit (that) offers an overview of the methods and techniques which can be used throughout the user-centred design process* [8]. The toolkit presented in the footnoted website is also accompanied by a publication, assumed to be used concurrently [89], which provides additional discussion on the motivation of its development. In the accompanying publication, the creators state that the toolkit is meant to bridge the gap between HCI and software engineering practitioners and researchers.

The toolkit itself is accessible online and bares similarity to the UsabilityNet.org's Methods Table, as described later on in a subsection of this chapter. It is organised into a matrix of columns, which represent the five phases of their proposed design process. These phases are *Research and Analysis*, *Concept*, *Design*, *Develop* and *Implement*. The identification of these phases informs the toolkit proposed in this dissertation and a similar structure was adopted. This was done as it appears to be less complicated and more streamlined then the IDEO's Human-Centered Design Toolkit. It also resembles the workflow processes described by participants in a survey that is outlined in the previous chapter of this dissertation.

[8] http://project.cmd.hro.nl/cmi/hci/toolkit/

However, Rotterdam University's ICT Toolkit has no less then 92 unique tools to be employed at various phases of their toolkit (sometimes repeating tool use in multiple phases), which again seems overtly complicated and over-engineered, but may reflect the processes of the targeted user-base. Still the description of tool use and application is limited to one or two sentences, or sometimes none at all. For the purpose of experience design practitioners and researchers, the tools proposed in this dissertation are much more simple to apply and use, and therefore have a much more shallow learning curve so that they can be deployed quickly and effortlessly, when compared to the toolkit offered by Rotterdam University.

3.4.3 UsabilityNet.org's Methods Table

The European Union's Framework V IST Programme conducted in the Usability Net project and was aimed at developing a prototype for a Methods Table [9] for use by usability practitioners and managers of EU projects. The prototype was developed through a collaboration of 18 organisations, companies and universities, and represents a substantial effort in developing a comprehensive and authoritative toolkit of methods specifically for use in the web usability field.

The Methods Table is a flash-based website that uses filters and links to information organised in a database of tools. The phases that are identified in the Methods Table include *Planning and Feasibility*, *Requirements*, *Design*, *Implementation*, *Test and Measure*, and *Post Release*. A total of 39 tools are presented, divided amongst the various phases. Tools could be filtered out depending on certain conditions, selected by the user of the Methods Table. These conditions include *Limited Time/Resources*, *No Direct Access to Users*, and *Limited Skills/Expertise*.

Overall the Methods Table offers a highly contextualised set of methods that have deep descriptions on their background and usage. It seems clearly targeted at the

[9] http://www.usabilitynet.org/tools/methods.htm

Title	Dat e	Number of Tools	Form	Phases	Intended User
IDEO's Human Centered Design Toolkit	2009	16 Tools 37 Steps	Book	3 Phases • Hear • Create • Deliver	NGOs and their targeted audiences
Rotterdam University's Human centered ICT Toolkit	2009	39 Tools	Table	5 Phases • Research & Analysis • Concept • Design • Develop • Implement	Software developers and Computer Engineers
UsabilityNet.org's Step-by-Step Usability Guide	2003	39 Tools	Table	6 Phases • Planning & Feasibility • Requirements • Design • Implementation • Test & Measure • Post Release	Usability Practitioners/ Researchers

Table 3.1: A summary of features for the discussed toolkits.

academic and academically-inclined commercial practitioner and researcher, with each tool substantiated with case studies and further reading. Emphasis is also centred around usability specifically, with little to no support for how each method can be incorporated into the design process [141]. The toolkit proposed in this dissertation is firstly aimed at the practicing experience designer as opposed to pure usability applications, and is meant to inform the design process specifically, and is again more simple in its application and use when compared to UsabilityNet.org's Methods Table.

3.4.4 Conclusion

A summary of features for the discussed toolkits can be found in Table 3.1. The main observations when comparing these three popular toolkits include a diversity of structure, phases of process, types and number of tools employed, as well as terminology.

This is most likely due to the diversity of authors involved in developing each toolkit, which ranges from design practitioners, social scientists, computer scientists, policy makers and engineers from the academic and commercial fields. Due to this diversity, the intended goals for each toolkit differs. This seems to be a trait of emerging multidisciplinary fields, and is apparent in the diversity of research that is published and presented at leading HCI conferences such as the ones sponsored by ACM CHI[10].

Besides their differences, there are some similarities of note. These include: supporting awareness of human-centred tools, organisation of tasks according to process phases, as well as authors providing summary information about each tool that is included in their respective toolkits. Yet even though there are similarities between toolkits, they differ in tools, audiences and goals, as well types and number of process phases, and types of data collected, enough so to warrant noting. Ultimately each toolkit has a targeted domain such as research, education, policy, practice, or even a combination of goals that makes each tool more likely to be used for a specific domain by a specific practitioner.

The multitude of differences described above is by no means a weakness of the general field of experience design. Instead, it can be seen as a strength. Due to the multidisciplinary nature of the field that encompasses HCI and experience design, the multitude of toolkits and methods can enrich the field, providing insight for future research. The toolkit of methods presented in the following sections of this dissertation are aimed at the experience designer, in order to facilitate growth in this specific practice within the field of experience design.

[10] http://www.sigchi.org/conferences

Chapter 4

Identifying: A Genealogy of Mixed Reality Lab Projects

One of the most basic difficulties when considering the authoring of this chapter was how to organise and categorise the projects of the Mixed Reality Lab (MXR). Funding sources and research goals were considered but were dismissed as being too arbitrary. Many of the projects encompass various and diversely overlapping themes. We needed to consider not only themes but the actual chronology of development for each project, and how one project would influence the trends for following projects. By considering time and influence, a family genealogy for lab projects was developed.

By organising linearly on a timeline, projects began to fall into place in regards to how they influenced one another before and after their conception. Generations of projects manifested themselves, as common threads appeared within themes that were developed congruently. Using these generations, not only were key topics identified but also their lineage regarding development. This phenomenon enables the lab with foresight into possible research topics for the future. The generations are categorised as follows:

- **The Proto-Project:** This generation represents the project that provides the archetypal themes in which all future projects are based on.
- **Gen-1 Projects:** These projects explored the augmented and virtual realities, and laid down key concepts for the study of mixed reality.
- **Gen-2 Projects:** This second generation of Mixed Reality Lab projects attempted to incorporate the real and physical world in contrast to the lab′s previous generation of projects.
- **Gen-3 Projects:** Cultural computing becomes important in this generation of projects and exploration beyond technical implementations are pursued.
- **Gen-4 Projects:** Fourth generation projects return to the hybridisation that was explored in second generation projects but this time combine physical and cultural computing.
- **Gen-5 Projects:** Finally, generation five projects uncover the quantum innovations that were developed in previous generations to develop projects that are far-forward thinking.

4.1 The Proto-Project: Human Pacman

Human Pacman (Figure 4.1) considers many topics that take prominence in all the projects conceived at MXR [13]. The system includes a wearable device that provides a HUD for the user. The HUD displays a graphical overlay onto a live stream of the real world. Simulating the game of Pacman [1], users are encouraged to collect virtual balls embedded in the real-world environment, while avoiding other players or *ghosts*. Other sensors in the system include an accelerometer and GPS to provide the user

[1]http://www.wired.com/science/discoveries/news/2007/10/dayintech_1010

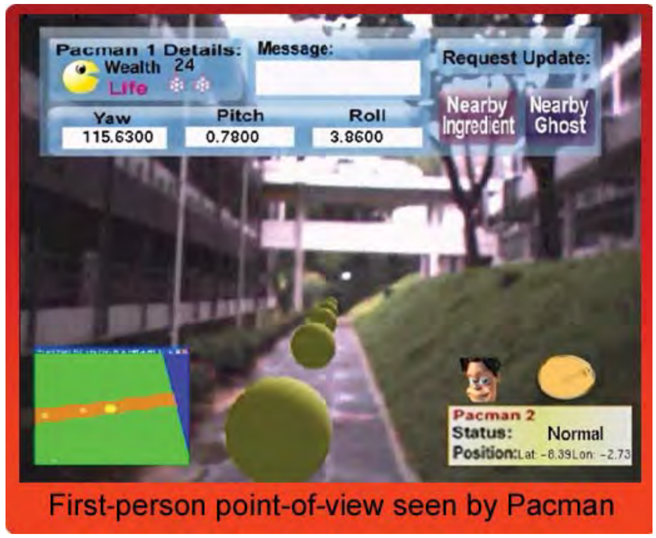

Figure 4.1: Human Pacman first person view.

with realtime data on their position situated in the play area (in this case, the real world).

Issues such as virtual and augmented reality, physical and natural user interfaces, entertainment, embodiment, wearable and socio-cultural computing are all raised in the project. At the time and still to this day, many of these themes drive the research in other labs, but it was this prototypical project that propelled MXR to its current research aspirations. As such it can be considered that Human Pacman exists as the proto-project in which the MXR Lab found its roots and inspiration.

4.2 Gen-1 Projects: Plant Story, Kyoto Garden

Early works of MXR focused on 3D images and graphical interaction using the principles of mixed reality, which allows the new methodology of ubiquitous human media to be implemented and expressed in action. It brought the opportunity of placing computation and interaction through and with the environment, rather than only on a desktop computer with a keyboard and mouse, in addition to incorporating sociological organisations of interactive behaviour. Using 3D graphical objects, tangible

Figure 4.2: Babbage Cabbage project.

interaction, and 3D sound, it was shown that ubiquitous human media allows the manipulation of objects in physical space to interact with 3D digital information. Kyoto Garden and Plant Story [17] are two example applications that align with these purposes.

For years, Kyoto in Japan was world famous for its unique garden art. Researchers in Kyoto University found out that designing a miniature sand garden could be a good aid for human mind therapy. However, designing a physical sand table is time consuming, and the white sand can really get messy. To solve this problem, they came up with a novel idea of applying ubiquitous human media and developed a virtual garden designing system, Kyoto Garden. Moreover, these activities took place in the context of the environment.

Kyoto Garden employs a wearable virtual reality apparatus that provides the user with a virtual view of a garden on top of a real world surface, in this case a table. Embedded on table are a series of fiduciary markers. Using a physical shovel tool that also contains a fiduciary marker, users can place virtual garden elements (plants, trees, flowers, ponds, hills, etc.) onto the real world table top surface and arrange each element as if landscaping a garden.

4.3 Gen-2 Projects: Metazoa Ludens, Poultry.Internet, Huggy Pajama, Age Invaders, MediaME, Living Media (dDNA and Babbage Cabbage)

After many projects that involves the virtuality paradigm, the MXR Lab began to explore more towards the reality end of of the Virtuality Continuum [105]. During this time, using the hypothesis that all interactive elements have a common foundation, embodiment, the lab shifted its focus towards embodied media with more emphasis on the physicality of the interactions. Inspired by some of the foundational paradigms of embodied media such as ubiquitous computing [150], tangible user interfaces [64] and interaction, the lab started to investigate the realism of embedding tangibility as another mode for communication. Projects like Living Media (dDNA) [16] and Babbage Cabbage (Figure 6.3) [42] discuss the values of using living organisms as display and interaction systems [16].

Babbage Cabbage uses the color changing qualities of Brassica Oleracea, or red cabbage. The cabbage is placed into a closed container that simulates a micro ecosystem. A server collects environmental data from the real world and then baths the cabbage in an appropriate PH balanced solution to alter the color of the cabbage. This color change signifies the current environmental conditions of the real world and allows the user to understand the real world environmental conditions as displayed through the cabbage colors.

Metazoa Ludens [134] and Poultry.Internet (Figure 4.3) [88] [138] discuss a possible future where pets can join us through the virtual world, where as Huggy Pajama (Figure 6.4) [136] [135] and Age Invaders [71] [74] [73] considers new forms of interaction among people.

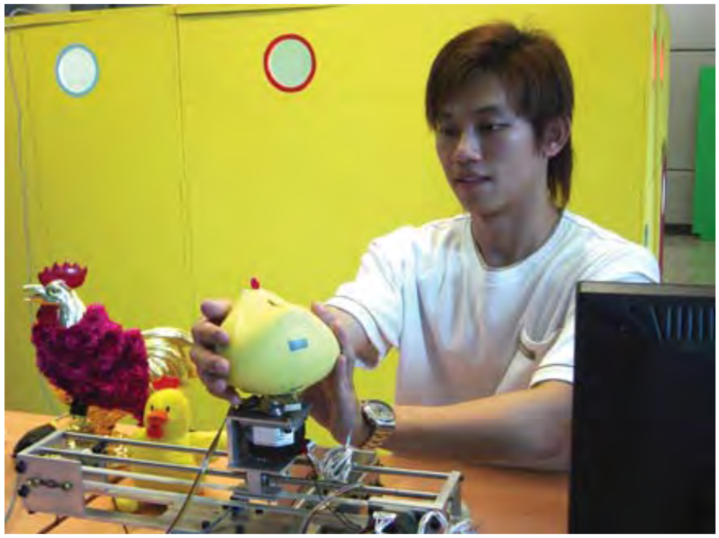

Figure 4.3: Poultry.Internet project.

A continuation of the haptic research conducted on chickens as described in a future chapter, the huggy Pajama project scales the wearable device found in the Poultry.Internet project for use by human beings. The primary interaction methodology is the same as the Poultry.Internet project, whereby telepresence users wearing the wearable jacket device can receive virtual yet physical hugs from a remote party. The remote party squeezes a device to simulate the hug, and a signal is sent over bluetooth to activate the jacket on the receiving end.

Age Invaders is a trans-generational system that spans both the physical and virtual worlds. Combining full-body interaction elements of screen-based play as well as gamification elements, users play a game similar to Space Invaders [2]. By stepping on LED embedded tiles, users wearing RFID embedded slippers can fire weapons at one another. This allows players of all ages to use physicality to play the game with one another. Other players can also participate using a web interface to place power-ups and other elements onto the physical gaming surface, thereby encouraging collective participation with the entire family.

[2]Space Invaders is one of the earliest shooting games and the aim is to defeat waves of aliens with a laser cannon to earn as many points as possible.

Figure 4.4: Huggy Pajama project.

4.4 Gen-3 Projects: Confucius Computer, Poetry Mix-up

Probing deeper into some of the inspirations behind previous generations of work, we identified that the cultural backgrounds deeply rooted in lab members were critical motivations for the work of MXR. The typical traditional Asian pet chicken inspiring the Poultry.Internet research project, and the increasing distances between young children and their grand parents inspiring the Age Invaders research project are some of the key examples in this regard. In addition, today′s rapid development of science and technology is pushing a decline in traditional culture. Younger generations accept new technology so quickly that most of them do not appreciate their heritage and art as their ancestors did [70]. Hence, through Confucius Computer and Poetry Mix-up, the next generation of lab work was deeply motivated towards providing an interface to allow users to learn, cherish and experience different cultures. Confucius Computer (Figure 4.5) is a new form of illogical computing [126] that models Confucius′ mind and personality, and enables users to experience his philosophies through modern,

Figure 4.5: Confucius Computer user testing.

everyday activities [70]. Similarly Poetry Mix-up [43] analyses and transforms a text message into a *mashed-up* poem allowing the user to become a poet themselves.

Confucius Computer's primary function is that of a chatterbot [3]. Users interact with it using a traditional keyboard and mouse interface. Users can have conversations and ask Confucius Computer various questions and it will respond using a database of Confucian edicts, providing esoteric or sometimes seemingly illogical answers so as to instigate creative interpretation by the human user.

Poetry Mix-up uses a similar natural language processing but this time the linguistic database is populated with descriptive words and phrases as found in popular poetry as opposed to Confucian edicts. Users can send an SMS text to the system, after which it will respond with a rehashing of the submitted SMS text in a poem-like style. This is displayed on a large display for all to see. An installation of this system can be found in the Singaporean-based Kent Ridge MRT station.

[3] A chatter robot is a type of conversational agent, a computer program designed to simulate an intelligent conversation with one or more human users via auditory or textual methods.

4.5 Gen-4 Projects: Petimo, AmbiKraf

Exploring further into the realms of cultural computing, this generation of lab work considers the tangible integration of cultural computing. Some of the key works of this generation, Petimo [12] and AmbiKraf [110], investigate this feasibility of the exploration of cultural computing through tangible interfaces, as well as the exploration of Japanese culture such as J-POP and Kawaii[4]. The spawning of the Keio-NUS CUTE Center during this time as a part of the Interactive and Digital Media Institute at the National University of Singapore, helped the MXR Lab collaborate with the Keio University Graduate School of Media Design in Japan. As a result it can be noted that Petimo (Figure 4.6) and AmbiKraf (Figure 4.7) explore the traditional cultures of Japan.

Like Lovotics, Petimo also employs the Japanese concept of Kawaii to direct the design and interaction of the system. Petimo exists as a small toy with a digital LCD screen. The screen displays emotive faces that appeal to the child user and also displays other information such as proximity to friends. Also contained int the device are RFID and accelerometer sensors. When two children meet and become friends in the real world, they can touch Petimos and become friends in an online digital social networking platform. This real world interaction ensures that children and first friends in the physical space before becoming connected online. This extra measure of precaution addresses the need for parents to know who their children are interacting with online.

AmbiKraf is a technology that exists in a number of formats. It's most successful iteration is manifested as a traditional byobu screen, often found in Japanese households and used as a space divider. Users who approach the screen are treated with a non-emissive, ambient animation using traditional Japanese decor motifs. The system

[4] *Kawaii* is the quality of cuteness in the context of Japanese culture. It has become a prominent aspect of Japanese popular culture, entertainment, clothing, food, toys, personal appearance, behavior, and mannerisms

Figure 4.6: Petimo robots.

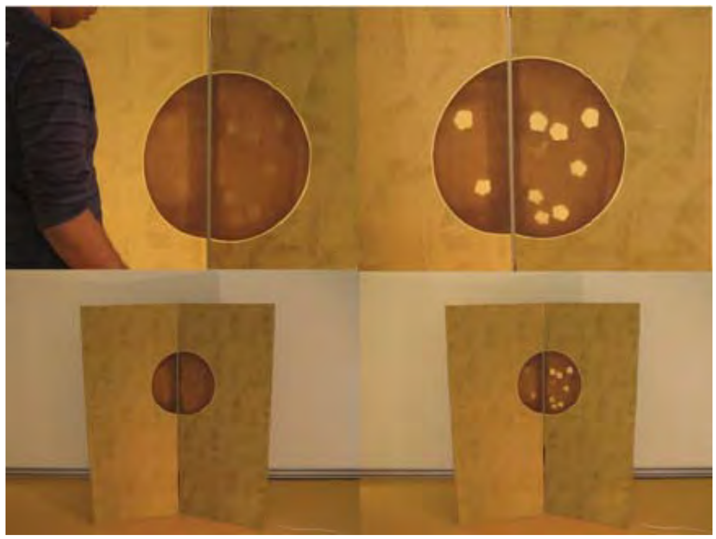

Figure 4.7: AmbiKraf Interactive Byobu screen.

uses ultrasound proximity sensors to know when a user approaches the screen. Embedded into the screen are Peltier semiconductors that heat and cool the surface fabric rapidly. Motifs are silkscreened onto the surface of the fabric using thermochromic ink. This allows the user to experience motifs that change subtly, altering the painted scene in realtime.

4.6 Gen-5 Projects: Smell and Taste, Food Media, Liquid Interface, Paper Interface, Lovotics

The latest wave of research at the Mixed Reality Lab (now the Keio-NUS CUTE Center) could be defined as *quantum leap* motivated. Without challenging the boundaries of research paradigms in an incremental step, the lab focuses on challenging the research paradigms itself to achieve quantum steps forward in its research. Ideas that seem heavily unrealistic, crazy or sometimes even termed as *Blue-Sky* are the key inspirations for this latest wave of research.

Smell and Taste is a project that attempts to digitally simulate the human experience of tasting and smelling. For the digital taste device, the user places the device on the tongue, and stimulates taste-buds found on the tongue using temperature as well as electrical current modulation. It addresses the lack of research regarding the engagement of other modalities by current communication technologies.

The Food Media project uses food as a communication interface [2]. It is a collection of systems that provides a telepresence dining experience for two users. The system consists a food printer that uses edible material to print messages onto bread. It also uses an electromagnetic table to simulate the serving of food from one user to another by moving plates found on the table towards and way from the diner. Finally a tablecloth using AmbiKraf technology provides ambient decor animations as well as a graphical messaging system. All these elements are brought together using a screen and camera, so that both diners have the experience of dining face-to-face. A Microsoft Kinect camera provides users with the ability to activate elements of the system using mid-air gestures.

Lovotics merges a computer simulated-version of the human endocrine system with robotics, in order to produce emotional behaviour by robots toward humans and vise versa [120] [121]. The Lovotics robot is described in detail in a future chapter.

Finally the Paper Interface and Liquid Interface projects explore new forms of tangible user interfaces. Paper Interface is a system that tries to digitise origami to be used as an input method [156]. Users are able to fold paper in front of a camera capture system. The system uses camera vision to sense the paper folds, which are then mapped to different controls in a tower defence-style game.

Linetic Liquid Interface (Figure 4.8) attempts to recreate the paradigm of the button by offering a malleable, self-configurable and shape-changing, 3D tangible user interface [79] [68]. Electromagnets are modulated to manipulate a pool of ferrofluid contained in a container housed above the electromagnet array. Users wear rare-earth magnets on their fingertips to actuate the fluid, forming different shapes using mid-air gestures. Sensing of the rare-earth magnets are done using Hall effect sensors, also contained beneath the surface of the ferrofluid. Users experience haptic feedback from the like-polarity resistance between the worn rare-earth magnets versus the actuated electromagnet, providing a real, physical sensation of pressing an invisible button. More details on the Linetic Liquid Interface system is explained in a later chapter.

A summery of the entire genealogy of Mixed Reality Lab projects, and the initial projects that lead towards the development of the Keio-NUS CUTE Center is represented in Figure 4.9.

Figure 4.8: Linetic liquid interface system.

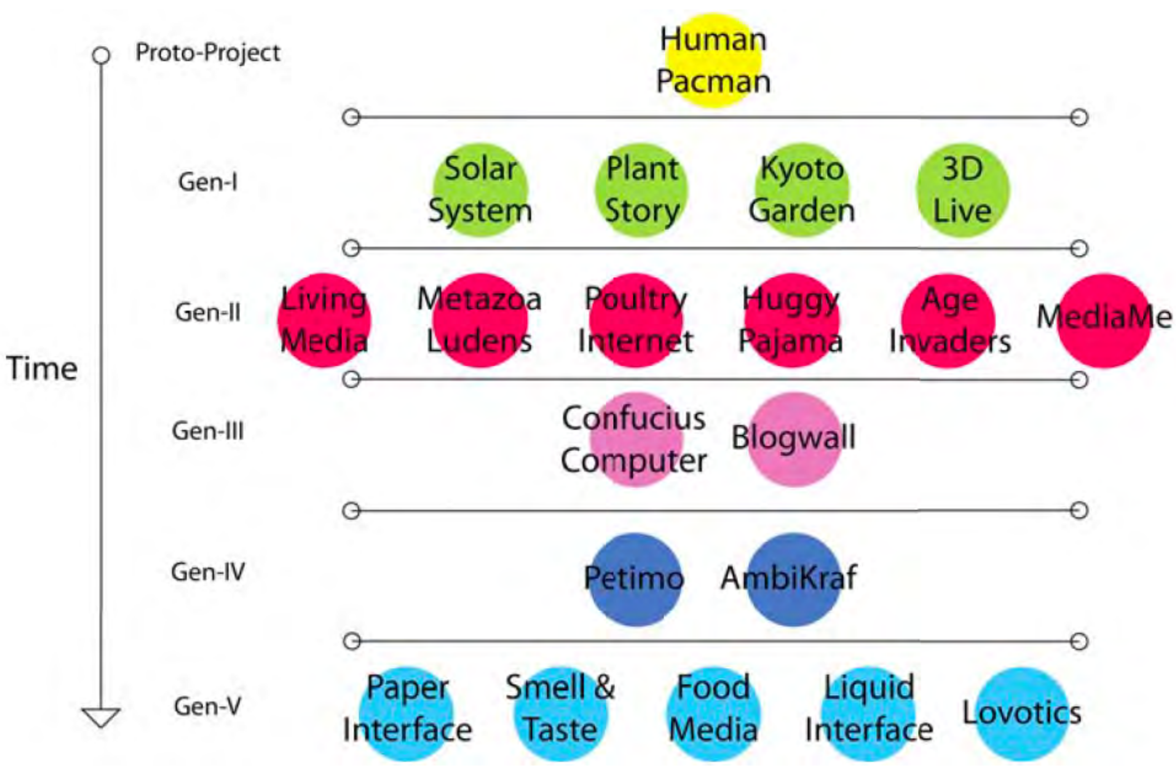

Figure 4.9: Generation versus Time matrix of projects.

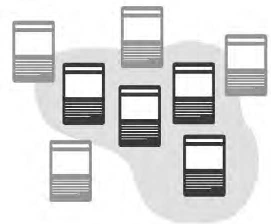

Figure 4.10: Identify and group projects that have semantic and/or contextual connection.

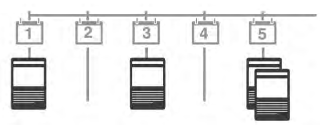

Figure 4.11: Using a timeline, situate each project in chronological order by either inception, release or initial publication.

Figure 4.12: Attribute characteristics to each project using descriptive keywords.

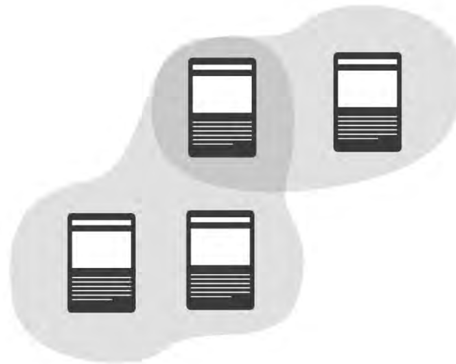

Figure 4.13: Look for overlapping patterns within the keywords that show correlations between various projects and begin to group each project using these keywords against the chronological order of each project.

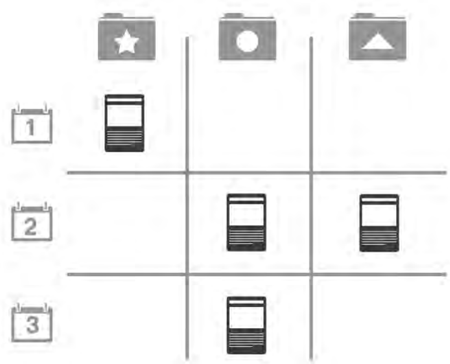

Figure 4.14: Identify the emergent groups of projects according to time and characteristics. These groups become levels on the genealogical family of projects.

4.7 Description of the Project Genealogical Tool and its Use

The Genealogical Tool is a method to identify thematic trends in a wide body of projects. The success of the tool is dependent on the sample amount of the projects analysed. The tool is meant to be a design research method so insight is the goal of the outcome, not hard data. It is meant to inform the user of the relationships between projects.

In order to use the tool, the following steps are required.

Step 1: Identify all projects that are to be analysed (Figure 4.10). These projects should have a previous semantic and/or contextual connection, such as being derived from the same research institute, developed by the same community of researchers, or within the same scope or field of practice.

Step 2: Using a timeline, situate each project in chronological order by either inception, release or initial publication (Figure 4.11). This can be a loose interpretation and exact dates are not required.

Step 3: Attribute characteristics to each project by looking to descriptive keywords (Figure 4.12). In the case of the above projects, keywords were derived from the various published works found for each project. Keywords can be derived from a number of sources. This includes creating a list from published works, abstract descriptions of the projects, etc. Be creative and describe the keywords as you see fit for your particular analysis.

Step 4: Look for overlapping patterns within the keywords that show correlations between various projects and begin to group each project using these keywords against the chronological order of each project (Figure 4.13).

Step 5: Identify the emergent groups of projects according to time and characteristics (Figure 4.14). These groups become levels on the genealogical family of projects.

Once all projects have been identified and classified, a genealogy can be uncovered. An example of this can be found in Figure 4.9.

4.8 Discussion

Using the above case studies, a method for extrapolating meaning from a body of work can help direct future development of interactivity projects. As shown in Figure 4.9, by looking towards thematic characteristics of a family of projects versus time, one can perceive the influences that a project has towards another, as well as a whole families of projects versus other families of projects. Developing a genealogy for a set of projects can inform the experience designer on what has been done, what has and will influence future projects, and where development could lead, as the genealogy makes apparent the gaps in overall development of several projects in a research direction.

As the first method in the proposed toolkit for experience designers, the genealogy method of organising and identifying thematic threads in previous works enables the interactivity practitioner a means to survey the state-of-the-art in regards to the concept that they hope to develop. Uncovering themes and influences can help direct future projects, whether inline with current research aspirations or to pivot from one topic to another.

Chapter 5

Conceptualising: Blue Sky Innovation

The Mixed Reality Lab (MXR) at the National University of Singapore has become renowned as a centre of excellence for interactive media and entertainment technology. The MXR Lab focuses its efforts on interactive and digital media technologies, combining the skills of engineers, scientists, artists and designers to create the future of digital interaction.

As the MXR Lab is located in centre of South East Asia and is funded mostly by public sources, many of the projects are directed by the situations and conditions that the region offers. Local influences and societal issues mix with the multiculturalism and the multidisciplinary characteristics of the lab's researchers. Paired with Singapore's cultural and economic position as a bridge between the east and west, in relation to the billions of people within short traveling distance (India, China, Indonesia, Australia), the MXR Lab lies at the convergence of many factors that makes the work of the lab unique.

Not only does the region offer distinct conditions that effect how the lab operates, but the researchers that the MXR Lab harbours also provide a wealth of diverse perspectives. Researchers at the lab both past and present hail from around the globe, including people from countries such as Australia, Brazil, Canada, China, Cyprus, Greece, India, Iran, Malaysia, Mexico, Pakistan, South Korea, Spain, Sri Lanka, Switzerland, Taiwan, the United States of America and beyond. All these experiences come together for better or for worse, as communication between researchers can be difficult at times, but always diverse and nurturing, with the common goal of doing high-impact research using what can be described as *Blue Sky Innovation*.

In this chapter we will outline the employment of *Blue Sky Innovation* by the MXR lab for ideation, collaboration and project generation, as well as discuss some major points of inspiration for MXR from various sources.

5.1 Blu Sky Innovation

Blue Sky Innovation is a process in which to develop as imaginative concepts as possible without being constrained by technical feasibility, commercial marketability or any other practical boundary.

It always starts with a crazy idea. *Let's use octopuses as display devices!* exclaims a member of the lab. Other members scoff at the statement, some think it genius, while others simply stare bewildered, slack-jawed and dumb-founded. This statement was in fact, the seed of inspiration that lead the Linetic team from the Mixed Reality Lab at the National University of Singapore to the project that is in development today.

The train of thought was this:

We have projects that explore living things as media. Other then purple cabbage, which we already use as a display embodiment for the Babbage Cabbage project, are there any other organisms that posses colour-changing properties? Certain reptiles change colour, as do some aquatic animals such as fish and octopuses. Aquatic means *liquid, right? Hey did you see those kinetic sculptures that Sachiko Kodama made? She uses magnetism to form them. They are pretty, but you can't directly interact with the material. Maybe we can use the controllability of magnetic fields to shape the ferrofluid to whatever we want, much like Magneto does to metal from the X-Men? Together with Hall Effect sensing, we can use the same magnetic field that agitates the ferrofluid to also sense and actuate it. This would enable us to create a shape-changing, three-dimensional and organic user interface* [60].

And thus the Linetic liquid interface project was born.

It is precisely these types of playful, inventive considerations that pushes the lab to explore novel technologies and interactions. Of course, not all projects from the Mixed Reality Lab are born purely from such thought processes. As it is mostly publicly funded, community, society and culture play immense roles in the development of its projects, but a great many of MXR's projects are inspired in such a manner, faintly akin to *mad scientist* methodologies. For example the Poultry.Internet project, in which pet owners can caress and hug their pet chickens remotely over the Internet, is also widely agreed among researchers in the field as being *a bit out there*, to put it politely.

Influenced by South-East Asian cultures and values, the Poultry.Internet project addresses the need for pets to co-exist with their human counterparts on the network [88]. Pets are important and instrumental to many people in having a healthy lifestyle. The chicken has traditionally been a loving pet and member of the family in rural, South-East Asian homes. By equipping a pet chicken with a remotely connected hugging vest, pet owners can remain physically and therefore emotionally connected to their pets even when away from home.

The system works as follows: a device (which can be described as a jacket or harness) is wearable by the chicken. Using bluetooth technology, a signal is sent to the wearable device that actuates a series of air pumps to simulate a "hugging" sensation. This is achieved through the grasping of a physical representation of the chicken over varying distances.

The idea to use the chicken as our pet of choice may seem a bit zany at first, but we must not ignore the wealth of research that chickens have been involved with. You could say that the chicken is the unsung author of many a research publication. Chickens are big business, and companies who deal in poultry have found that chickens; known as highly emotional creatures, are more productive at laying eggs when haptically stimulated. Indeed like humans, chickens need love too [138].

Speaking of love, humans need to feel and express it very much, so who is to say that we cannot share this essential emotion with robots? Most researchers would think that simulating the emotion of love is an impossible research area (almost as impossible as getting a date during conference submission deadline time for many of the researchers at the lab), but since one of the main topics of research for the Mixed Reality Lab is *Feeling Communication*, understanding and digitally recreating this most important of emotions was a challenge that was naturally accepted.

By simulating the human endocrine system using complex algorithms developed by researchers at the lab, they are able to replicate some of the hormonal functions that occur in humans, which was then transplanted into a custom-built robot. This research, combining a software-based endocrine system and robotics is called Lovotics [120] [121].

Lovotics is embodied by a cute robot following a kawaii model [1]. The robot itself is covered with fur and makes cute sounds, similar to R2D2 from the film series, Star Wars. Sensors are embedded into the robot that help it approximate touch, sound and proximity. Depending on the duration and quality of the interaction by a human counterpart, the artificial intelligence system calculates the affective input from said human counterpart and responds accordingly.

[1] A Japanese term, it means the quality of being cute, or items that are cute.

As examples, these are really just the tip of the iceberg when it comes to some of the more thought provoking projects from the Mixed Reality Lab. Always aiming for as imaginative research as possible, many of the projects are birthed from ideas developed in previous projects. Writing this chapter gives MXR a chance to evaluate and analyse how they develop ideas in retrospect. Because of this opportunity, we were able to categorise the lineage of our project development, and have created a genealogy for projects that was discussed in the previous chapter.

5.2 Geographical Location

Singapore is in an interesting geographic situation within South East Asia, where the Mixed Reality Lab calls home. A place where many cultures and societies intersect, Singapore has inhabitants from all over Asia and the rest of the world. Singapore is also a gateway to the world's next billion people. In close proximity to Malaysia, India, China, Indonesia and Australia, Singapore sits at a point which connects all these locations. Because of this, Singapore's strategic importance is crucial for the development of the region[2]. In addition, Singapore's geophysical location has sparked many collaborations. Combined with positive governmental policy and the implementation of more then adequate infrastructure, Singapore attempts to become a central hub for technologies especially in the interactive digital media sector. With this generous support from the state, universities and other academic institutions are widely encouraged to initiate international collaborations in order to expand Singapore's socio-technological horizon.

The Mixed Reality Lab reflects this diversity with researchers hailing from around the world. This diversity offers the lab various perspectives, sometimes not always agreeing, yet always nurturing, interesting and stimulating.

[2]Michael Yap at TEDxUSC (http://www.youtube.com/watch?v=wA02h_uPlJY)

The geographic location and the spectrum of differing cultures housed by the lab are also reflected in the MXR Labs concepts, working methodologies and project outcomes. As there is no fixed culture or strict guidelines imposed in the lab, the lab members are always inspired by the cultures of their peers, societal problems, etc. For example, one of the popular projects of the lab, Age Invaders reflects one common societal issue in Singapore. With Age Invaders MXR researchers try to re-build the increasing gap between the elderly and the young [74]. By offering technological mediation to these two generations, Age Invaders lets the elderly and the young play computer games using their own bodies as physical avatars [71] with the working parents joining in over the Internet, the whole family is re-united through technology [71].

Being in Singapore, the lab is literally surrounded by a fast-paced and modern society. Probing deeper into this society, and as most of our lab members complain about, we can clearly see how the youth of the new generation is losing their grip with old cultures. Because of a majority Chinese demography in Singapore, Confucian teaching is of great philosophical importance to the community [70] [14]. In order to address this demographic preference, the Confucius Computer project attempts to contemporise the teachings of Confucius through the use of a digital chat interface. It aims to facilitate intergenerational communication by enabling young and old to interact and explore an ancient Asian cultural heritage. The importance to not only embrace the traditions and cultures of the surrounding region but to also promote them on the international stage has become second nature.

MXR often has many visitors from different backgrounds, professions, etc. visiting our lab. The central nature of Singapore as a transportation hub in the Asian region has immensely encouraged these visitors to drop by and get an insight to our work, have interesting discussions, and so on. Often these talks have inspired many projects and different perspectives of thinking. Similarly talking about slowly fading Asian textile cultures and traditions with Japanese textile artists has inspired the project AmbiKraf to breath life back into textiles [110]. This project has developed a new technology that animates fabrics [110]. But how does this help these traditions? Here researchers at MXR take differing Asian textile cultures and traditions such as Japanese Byobu art, Sri Lankan Batik art, etc. and re-integrate them with our technology. Researchers at MXR hope that this contemporary rebirth of the textile into an interactive textile tradition re-engages an old audience, finds a new one, and in the process preserves said cultures for the 21st century.

On a local level, the MXR Lab has always used its projects to engage with the Singaporean public. Embracing themes that are inspired and generated by our society, many of our projects are also featured in public venues. It has demonstrated technologies at community festivals, the Singapore Science Centre, and have an interactive exhibition situated at one of Singapore′s newly built public transportation stations. Feedback from the public is very important to the lab, as many of the MXR projects attempt to address the needs of the Singaporean community.

5.3 Collaborations

Employing practitioners from backgrounds such as engineering, design, fine art, life sciences, social sciences and more, the MXR Lab balances on the cusp of various fields, where projects exist between the lines of traditional knowledge.

Even though such multi-talented, multi-disciplinary teams are essential for many of the projects and collaborations in the lab, there are still great difficulties when engaging internally between collaborators, and externally to community and industry partners.

Internally, each and every researcher in the lab is unique. People are experts in specific fields, come from different cultures and have varying working methodologies.

On a professional level, designers and engineers can use terminology that is specific to the jargon of their respective fields. What one term means to one group of professionals could mean something completely different to another. To have a common language, in which all members of the lab can communicate their ideas with, is key.

Because of this need, not only do projects cross the boundaries of various fields, but its developers must also do the same. Lab members are encouraged to learn the practice of their fellow members and it is not strange to see engineers using design-driven research or designers tinkering in order to learn electronics. Understanding the language and knowledge of their fellows is important in order to communicate and collaborate effectively.

This sharing helps researchers engage people of all backgrounds, not only because of a mutual understanding of the skills involved that are needed for every project, but also because of the sense of mutual respect and understanding for one another as individuals. This becomes doubly important when collaborating with industry partners and in ideal situations, it also communicates to MXR partners that lab teams are knowledgeable and cohesive.

5.4 Positioning in Relation to Similar Labs

MXR Lab shares many attributes with other labs and institutions working in overlapping fields. Indeed, many of the MXR Lab researchers stand in awe and wonder at many of the advancements produced by peers from various labs around the world.

The first and most famous lab that MXR can compare itself to is the Massachusetts Institute of Technology Media Lab. In many respects, both labs share the same passion, curiosity and vision. Multidisciplinary collaborative methodologies and the exploration of novel media drives research at both labs similarly, whereas funding sources appear to be the main difference between both labs. Privately funded research often needs to facilitate the expectations of the granting body. The MXR Lab is funded publicly by the Singaporean government, which offers us fluidity and wider experimentation as we do not necessarily need to fulfil marketable requirements.

Another lab similar to our lab is the Mixed Reality Lab in Nottingham[3], which works with mixed reality concepts to drive and develop projects, but where the Mixed Realty Lab in Nottingham focuses on using mixed reality for application in everyday life, the MXR Lab covers areas that could sometimes be considered unfit for public consumption.

In fact many other labs such as the UbiCompLab in Taiwan[4], the HIT Lab in New Zealand[5], and the Tachi Lab in Japan[6] conduct research that compares with some of the areas that the MXR Lab is interested in, but due to our wide scope and broad internal and external influences, paired with the concept of *Blue Sky Innovation*, these factors offer the MXR Lab the agility to explore a far fetching gamut of research topics. Nothing is beyond the scope of interest for the MXR Lab and if members are not experts in a new field of interest, researchers learn or are recruited to cover new and interesting project developments.

5.5 Description of the Blue Sky Method and its Use

What knowledge of existing systems and interaction methodologies does one have before the onset of conceptualization? What is the immediately available information one has to base a brainstorm on? What are the previous works that inspire one to conceptualize a new work? How do these works influence other works? Understanding

[3]Mixed Reality Lab, University of Nottingham (http://www.mrl.nott.ac.uk/)
[4]UbiCompLab, National Taiwan University (http://mll.csie.ntu.edu.tw/)
[5]HIT Lab (http://www.hitlabnz.org/wiki/Home)
[6]Tachi Lab (http://tachilab.org/)

the thematic trends in previous systems can act as touchpoints of inspiration, as outlined in the following chapter regarding the genealogical tool proposed in this dissertation. Knowledge can be considered observable and measurable.

This dissertation does not go as far so as to suggest that one should employ alcohol-induced creativity [129], but a certain lucidness is needed to allow one's thought process to wander. In affect, the *Blue Sky* tool is a mode to express out-of-the-box thinking, in an attempt to instigate serendipitous results. Serendipity in scientific discovery is defined as an unexpected experience characterized by an anomalous observation and valuable outcome and dependent on an individuals strategic insight [104]. Other fields such as business [38] and education [75] have alternate definitions for serendipity, but for the purpose of this dissertation, and because of the situational conditions of CUTE, Merton′s definition is suitable.

Serendipity may not seem like a variable mode of scientific discover at the onset. Shcaefel and Dumais argue that chance must be synthesised into insight for it to be useful [4]. Yet they also argue that the inventor′s perception may be enhanced to increase the opportunity for serendipity [4]. This could also lead to more creativity and insight generation.

Furthermore the phenomenon of serendipity does not occur without context. McCay-Peet and Toms argue that serendipitous discovery is precipitated by various conditions [102]. Influences from contextual factors such as working environment, collaboration and working conditions factor into serendipitous discovery. The conditions specific to serendipitous discovery at CUTE are outline in the sections above. For the *Blue Sky Method* to work appropriately, the understanding of such contextual conditions are needed in order for the method to be enacted.

McCay-Peet hypothesises that serendipity may be facilitated through the design of a system sensitive to external and internal context [101]. Therefore the questions presented in order to direct the use of the *Blue Sky Method* can be classified as external and internal factors.

To outline a specific method in steps in order to use the *Blue Sky Method* are difficult to precisely prescribe. Instead, the understanding of the conditions uniquely attributed to the context of its use must be identified. Questions that should be self-reflectively asked have been adapted from the precipitating conditions outlined in [101], and are based on the model proposed by Cunha [38].

A preliminary set of questions to consider are offered in the following subsection.

5.5.1 A Preliminary Set of Questions to Initiate the Blue Sky Method

- *What is the readily available knowledge one has at the onset of ideation?* What knowledge of existing systems does one have before the onset of conceptualisation? What is the immediately available information one has to base a brainstorm on? What are the previous works that inspire one to conceptualise a new work? How do these works influence other works? Understanding the thematic trends in previous systems can act as points of inspiration, as outlined in the previous chapter regarding the genealogical tool proposed in this dissertation. Knowledge can be considered observable and measurable.

- *What is the motivation for the work, project or system one chooses to develop?* Is the work intended to solve a client′s parameters? Is it to develop a novel scientific contribution? Is it intended as a provocative artwork? Is it a combination of many motivations? Understanding the motivational underpinnings of the concept is useful in providing a direction for the ideation process to follow. Motivation can be considered observable and measurable.

- *What is the behaviour of the researchers and practitioners when ideating?* What is the working culture that the researcher or practitioner works in? What is the working style and method of the individual in regards to their practice? Do they work in a team? How does the team synthesise their skills? Understanding the working habits of the people involved in the ideation and creation process can provide foresight into the factors that will influence the direction of ideation. Behaviour can be considered observable and measurable.

- *What are the tasks involved in developing the proposed work, project or system?* What are the tasks needed to develop the work? How will issues be identified and solved as they arise? How will the completion of one task influence the next? What is the overall process flow that should be employed for the project? Understanding the process of development can influence the direction of the project. Often during the process of development, new insights and directions can occur. Tasks can be considered controllable and manipulatable.

- *What is the environment in which the ideation process occurs in?* Are people ideating in a democratic format? Is the environment setup for free thinking? Are you employing a structured process for ideating? Is this happening at a laboratory? A classroom? A meeting room? A bar? The environment and its situational context can influence the nature of lateral thinking. Cultural and societal norms can also play a role in the development of ideas and concepts. Realising these environmental factors can help steer the direction of ideas as well as the acceptance and rejection of certain concepts. Selection of location as well as understanding the overall environment that the ideation process occurs in can significantly influence the creativity of the ideas generated. The environment can be considered controllable and manipulatable.

- *Who are the other people involved in the ideating process? What are their skills and interests?* What are the skills needed to develop the work? How will multiple skills combine in order to solve any issues that arise? How will the completion of one task influence the next? What are the team members interested in? How will this influence the ideation process and outcome? Are there any personal concerns when working with these people? Depending on interest and skill set, concepts generated in the ideation process could pivot in various ways depending on the perspectives of the people involved. Also working relationships, culture and other personal factors could influence the collaboration process. People can be considered controllable and manipulatable.

In summery, knowledge, motivation and behaviour may be measured and observed, while task, environment and people may be controlled and manipulated. Being conscious of these influencing factors is key to using the *Blue Sky Method*. Using the set of questions above, a formulation of enquiry can be supported as they can be seen as the precipitating conditions to serendipitous knowledge exploration.

5.6 Discussion

This chapter has outlined the identifiable conditions in which serendipitous research discoveries are conducted at the Mixed Reality Lab in the National University of Singapore. A balanced combination of multidisciplinary teams, geography, collaboration and positioning in relation to other labs around the world have generated the ideal conditions for *Blue Sky* research processes and outcomes.

Although many scientific discoveries have been found through serendipitous means, there are several perceived limitations when conducting research using the Blue Sky Innovation research methodology. One such limitation includes the difficulties when applying for research funding. Other limitations include the excess of resources needed to be able to pivot research concepts radically.

Regardless of these limitations, the research outcomes of such practices are apparent. As a centre for innovation, the precursor to the Keio-NUS CUTE Center, the Mixed Reality Lab, has developed several interactions and products that have had widespread acceptance both in the academic and socio-cultural realms. The amount of output that the lab has produced is ample enough to serve as a dataset in which patterns and themes within the field of interactive media can emerge.

Both a tool and an attitude towards conceptualisation of interactive and experiential projects, to reiterate, *the Blue Sky Innovation method is a process in which to develop as imaginative concepts as possible without being constrained by technical feasibility, commercial marketability or any other practical boundary.*

Though not practically feasible when used in later stages of ideation, by employing such a method at the very early states of project ideation and conceptualisation, it ensures that the most creative and innovative ideas can flourish, which can later be scaled-down due to design and resource constraints.

Chapter 6

Characterising: Analogness and Digitalness

Since the advent of the lever and button[1] we have seen an increasing amount of methods in which users interact with machines. Major breakthroughs in interface development such as tangible user interfaces (TUIs) [64], multitouch interfaces [151], and more recently, organic user interfaces (OUIs) [145] have afforded new ways for HCI researchers the means to create innovative, interactive systems.

Likewise theories of the relationship between interactive systems and users has been explored though concepts of embodiment ever since Descartes published his Mediations on First Philosophy [30] right through to Merleau-Ponty and his theories regarding embodiment [103], to Dourish′s incorporation of phenomenology into HCI [33], and beyond. With the dawn of ubiquitous computing, Mark Weiser attempts to extend this notion of phenomenology with new digital computing technologies. By *weave(ing) themselves into the fabric of everyday life*, Weiser tries to bring digital technologies into the analog world around us [150].

[1]DeRouchey, B. (http://www.slideshare.net/billder/history-ofthe-button-at-sxsw)

However, as we move into the 21^{st} Century, a dichotomy between what is analog and what is digital has emerged. This duality provides an opportunity to discuss and analyse interactive systems that have tendencies towards either analog-like or digital-like interaction characteristics, or even a hybrid of both. Here, the duality addresses the relationship between the user and the interactive interface in terms of the action by the user and the reaction of the system and vice versa.

Using case studies derived from the extensive body of published works developed and studied at the Keio-NUS CUTE Center at the National University of Singapore, we outline in this chapter the characteristics of *analogness* and *digitalness* regarding the relationship between interactive systems and users. From this point we then define a taxonomy for types of interactive systems (analog-like, digital-like, hybrid-like), and propose a continuum for analog-like-to-digital-like interaction.

By establishing the *Analogness-Digitalness Continuum* (ADC), we can then begin to define a new methodology for designing novel interactive systems based on their analog-like versus digital-like tendencies, and propose a new field of research to counterbalance interactive digital media (IDM) [111] based on interactive analog media (IAM).

The main motivation to create such a method of classification is two-fold. Firstly, the ADC in of itself can be used to study and classify all interactive systems. Secondly, the ADC in conjunction with the proposed characteristics found in this manuscript can be used to direct development of such systems in order to achieve particular styles of interaction and user/system relationship.

In the next section we define *analogness* and *digitalness* for interactive systems. Following our definition of *analogness* and *digitalness*, the next section presents a prototypical example of an interactive analog-like interface, which analyses some well-known works and concepts in interactive systems research, in terms of their *analogness* and *digitalness*. We then introduce our grounding characteristics to define the *analogness* or the *digitalness* of an interactive system. These characteristics are further expanded and explained in the next section, which characteristics systems with analog-like and/or digital-like interactions. Next in the Case Studies section we analyze some works of the Keio-NUS CUTE Center, and then move to propose the *Analogness-Digitalness Continuum*, after which we conclude the chapter through discussion.

6.1 Defining *Analogness* and *Digitalness*

In the past, philosophers such as David Lewis discussed the troublesomeness of distinguishing analog and digital classifications [90]. He mentions that even though it is relatively easy to make the distinction in practice, the analysis of such representations from a philosophical standpoint is difficult.

Yet from a computational standpoint, the distinction is much more defined. Dale and Lewis attempt to describe analog and digital data: *Analog data is a continuous representation* (as represented in Figure 6.1), *analogous to the actual information it represents. Digital data is a discrete representation* (as represented in Figure 6.2), *breaking the information up into separate elements.* [27].

From Dale and Lewis′ definition in comparison with concepts of embodiment discussed in the previous section of this paper, we can derive and adapt our own definition for analog-like and digital-like interaction:

Analog-like interaction create a continuous experience for both the user and the system, analogous to the actual information represented. Digital-like interactions create a discrete experience, segregating the users′ interaction with information and the system's interaction with the user into separate events.

Adopting this definition helps us outline the differences between interactive systems and highlights features that are disposed to analog-like versus digital-like ten-

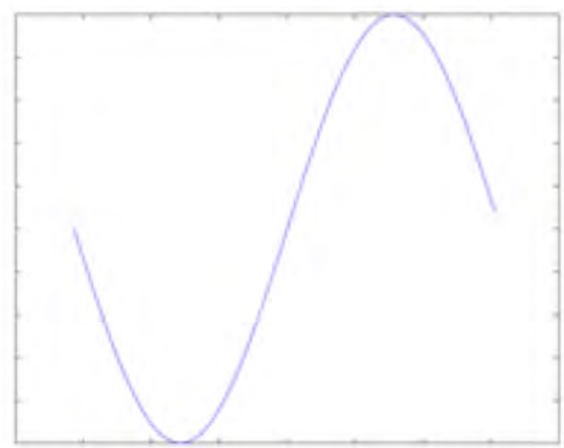

Figure 6.1: A continuous, analog signal.

Figure 6.2: A discrete, digital signal.

dencies when representing interactive content to users. The differences can then become identifiable characteristics that could help in the development of interactive systems. Yet before continuing, an analysis of well-known HCI projects using the above-proposed definition should be made.

6.2 An Analog-like / Digital-like Analysis of Prototypical Interfaces

Adhering to this early classification of the *anlogness* and *digitalness* of interactive systems, we investigate Ishii′s work on Tangible Bits [64], in this context. We investigate the work presented in Tangible Bits due to its wide acceptance as the work that defines the notion of *tangible bits.* Furthermore, to our understanding, this work contains both digital-like and analog-like affordances that would help to further define the *anlogness* and *digitalness* of interactive experiences.

Tangible Bits represents a wave of new interface technologies that lets users grasp and manipulate digital information. Thus, the work here mainly focuses on the interface aspects of the interaction. In completing the equation, this chapter introduces the user into the scenario and addresses her involvement with the interface, the interaction and the embodiment of these aspects with relation to the user.

The vision of Tangible Bits is introduced through the three main design projects of metaDESK, transBOARD and ambientROOM. These projects present various ways of representing digital information through tangible objects. Thus here, we analyse some of these interfaces and interactions in terms of their *anlogness* and *digitalness.*

In the metaDESK, there are few tangible objects such as the phicons, etc. which represents various interactions for the user. They are used on a tabletop setting to which the graphical user interface is projected on to the surface. The user interacts with this graphical user interface (GUI) using tangible objects. Here, the phicons are picked up, placed, rotated, etc. by the user on the tabletop. These various actions represent various reactions such as identification, rotation, zooming and so forth in the GUI. Thus, these intuitive actions that we would use on such a tangible object represent the interactions with the system. In addition, the interaction is continuous, as we would interact with a tangible object without having to follow a discrete set of steps. Thus, the actions are embodied within the object or the interface. Hence, the phicons interface contains analog-like characteristics.

However, the output of the system here is a projection onto the tabletop. According to our earlier discussions this creates a dichotomy between the interface and the media, as it is not combined in a singular fashion. The interface (in this case, the table) does not have any particularly inherent affordance for representation of media or content. Therefore simply changing the table to a wall would not have any effect on the media or the content, as it is a digital representation that is displayed as the output. This disconnection we see as a main characteristic of a digital-like system.

These key characteristics are seen in some of the early works of tangible user interfaces. In [64] again, similar to TUIs, physical pucks are used on a sensetable as the input devices. By relocating and rearranging these pucks the user can change various parameters of the system that is visualised through the output image projected onto the table. Here too, the use of physical pucks and their various orientations are intuitively engineered. This can be seen as an intuitiveness that leads to continuous interaction with this interface. In other words, the change in the orientation of the puck directly changes the parameters and causes a continuous interaction. However in contrast to this analog-like tendency of the input, in terms of the output of the system, once again, the projection creates a dichotomy between the projected content and the interface. The projection is not defined by the interface. Even if the interface was a scroll button of a mouse, or the output surface was a tabletop or a wall, the projection is unhindered. As mentioned before, this discontinuity or the discreteness between the output and the interface becomes a characteristic of a digital-like system.

This use of analog-like characteristics and digital-like characteristics presents a hybridised architecture for these technologies. This is one of the key characteristics of tangible user interfaces where the focus is mainly on the tangibility of the interface rather than its form or function. In addition, it only focuses on the interface and limits its involvement of the user and her role in the interface. Thus, the analog-like and digital-like characteristics are mixed more often in these technologies.

Moving ahead from tangible user interfaces, researchers from more recent fields such as organic user interfaces started refining the characteristics of the interface itself [145]. Adhering to the three tenants of OUIs, *input equals output*, *form equals functions* and *form follows flow* [145], OUIs focused on the ergonomics of the interface to define its function and interaction. Thus, textiles, paper, and many other forms of flexible daily objects have the potential to become interfaces. Considerations of the ergonomics of the object helps the interfaces to encompass more analog-like characteristics to its design. However, here too the lack of consideration of the user′s involvement of the design of the interaction process has led to these systems to be more hybrid-like (as in both analog-like and digital-like) in nature when considering characteristics of *analogness* and *digitalness*.

For example, many of the recently developed fabric displays too fall under this category of organic user interfaces. However, there is a keen interest in combining media such as light emitting diodes (LEDs) and electroluminescence materials [18]. Thus, in the context of an embodied interface, such displays or interfaces fall short of using extended characteristics of the textile itself and rather superimpose a foreign object or material, creating a vivid dichotomy between the material and the interface. Hence, the users interaction is in fact with the LED or the EL wire, which represents the digital information and not the actual fabric itself as an interface. Therefore, the extension of the interface is to a foreign material making it more digital-like in nature.

Analysing these concepts such as tangible user interfaces and organic user interfaces makes it clearer that most of these concepts focus their definitions towards the interfaces themselves. Thus, in determining the *analogness* or the *digitalness* of the interface and more importantly the interaction, we stress the importance in considering the user and the notion of embodiment towards the user interface. Just as Mark Weiser depicted that the *most profound technologies are those that disappear* [149], the extension of the interface and more importantly the interaction of both the user and interface as a single embodiment becomes important throughout the definition of the *analogness* and the *digitalness* of the interaction experience. Thus, in defining these characteristics and analysing the previous concepts, we identify the following main points to define these characteristics:

- Analog-Like Interactive Systems: Content and Media are Singular in Embodiment
- Digital-Like Interactive Systems: Content and Media are Dichotomistic in Embodiment
- Analog-Like Interactive Systems: Interaction is Continuous
- Digital-Like Interactive Systems: Interaction is Discrete
- Analog-Like Interactive Systems: The Interface is Intuitive
- Digital-Like Interactive Systems: The Interface is Mediated
- Hybrid-Like Interactive Systems: Fulfills Some or All of the Afore Mentioned Rules

6.3 Characteristics of Systems with Analog-like and/or Digital-Like Interaction

- **Analog-Like Interactive Systems: Content and Media are Singular in Embodiment**

  Just as analog data in a computational system can be described as analogous to the actual data it represents, so to do analog-like interactive systems represent data to users as a singular embodiment where content and system are one and the same.

- **Digital-Like Interactive Systems: Content and Media are Dichotomistic in Embodiment**

  In digital computational systems, data is represented discretely, breaking up information into separate elements. A digital-like interactive system therefore separates content and interface so that data delivered by the interactive system can be changed and replaced by different data. Content and media are therefore mutually exclusive and represent two separate embodiments.

- **Analog-Like Interactive Systems: Interaction is Continuous**

  Much as analog data is a continuous and infinite representation, so is the interaction method in analog-like interactive systems.

- **Digital-Like Interactive Systems: Interaction is Discrete**

  In digital computational systems, data is finite and compartmentalised into limited data sets. Therefore digital-like interactive systems are precise in their interactions, meaning that there is a limited selection of variables when interacting with the system.

- **Analog-Like Interactive Systems: The Interface is Intuitive**

  From a user standpoint, analog-like interactive systems feel natural to use. They are extensions of the body and when used, become part of the embodiment of the user.

- **Digital-Like Interactive Systems: The Interface is Mediated**

  Digital-like interfaces are always accessed through a discrete interface method or technology. Users must use a tool with a precise function and method of use in order to interact with the system.

- **Hybrid-Like Interactive Systems: Fulfils Some or All of the Afore Mentioned Rules**

  Hybrid-like interactive systems exhibit some or all of the characteristics of both analog-like and digital-like interactive systems.

The characteristics of systems with analog-like and/or digital-like interaction can be used as a lens to analyse the relationship between interactive systems and users. In the following section, we will attempt to differentiate projects by their *analogness* and *digitalness* by applying the characteristics to a series of case studies.

6.4 Case Studies

In this section we will analyse six existing interactive systems from Keio-NUS CUTE Center, in the context of interactive analog and digital media. By apply the characteristics described in the last section, we divide these projects into three main categories: analog-like, digital-like, and hybrid-like.

6.4.1 Analog-like Relationship Between User and System

In this section we discuss projects with analog-like characteristics by looking at the Living Media and Huggy Pajama projects.

Living Media [16], also known as Babbage Cabbage, is a new form of interactive ambient media using living organisms to communicate social, human or ecological information, such as the status of health, environmental pollution, and remote interactions between friends. As shown in Figure 6.3, in a Living Media system, information is semantically coupled into a living plant, in this case cabbage.

Babbage Cabbage uses the colour changing qualities of Brassica Oleracea, or red cabbage. The cabbage is placed into a closed container that simulates a micro ecosystem. A server collects environmental data from the real world and then baths the cabbage in an appropriate PH balanced solution to alter the colour of the cabbage. This colour change signifies the current environmental conditions of the real world and allows the user to understand the real world environmental conditions as displayed through the cabbage colours.

Situating Living Media with the proposed characteristics, it can be seen that Living Media communicates information through the intrinsic properties of living creatures, such as shape-changing and colour-changing characteristics. Therefore content and media are naturally singular. In terms of the continuousness of user interaction, Living Media uses cabbage to perform the output with the slow and gradual change of colour under chemical solution with different pH values. Furthermore, the input information is from the natural environment, which is continuously changing; this also implies that there is no limited or specific set of input data for the living media, which means users can map any type and range of variable to ambient Living Media. In addition, the results of a user study for Living Media shows that it is visual and easy for user to understand information data through, and generate empathy for natural living creatures. Therefore, Living Media falls in the category of an analog-like interface.

Figure 6.3: One of the Living Media projects, Babbage Cabbage was demonstrated at Laval Virtual 2009 in Laval, France.

Huggy Pajama [137] is a wearable system to allow parents and children to communicate over the Internet by physically hugging each other through a novel hugging interface. A demonstration and user study of the system is depicted in Figure 6.4.

The primary interaction methodology is based on a haptic interface, whereby telepresence users wearing the wearable jacket device can receive virtual yet physical hugs from a remote party. The remote party squeezes a device to simulate the hug, and a signal is sent over bluetooth to activate the jacket on the receiving end.

In the Huggy Pajama system, the pajama with embedded actuators generates the remote physical hug. Without wearing the pajama, users cannot experience the remote hugging interaction, which means the hug sent through the Internet cannot be separated from the pajama. The input data for Huggy Pajama, such as touch and pressure, are continuously sensed in a wide range by the embedded Quantum Tunnelling Composite (QTC) circuits. On the other side, the air pressure in the pajama changes slowly in a continuous way under a closed-loop controlling system. According to the user study, users showed interest to use Huggy Pajama to hug each other remotely, and it does not take effort to use the interface, as only touching

Figure 6.4: User study and demonstration of Huggy Pajama in Singapore, 2010.

input is required. With this analysis, we categorised Huggy Pajama as an analog-like interface.

6.4.2 Digital-like Relationship Between User and System

In this section we discuss projects with digital-like characteristics by looking at the Poetry Mix-up and Confucius Computer projects.

Poetry Mix-up [43] is an extension of the existing text-messaging paradigm to a new level of self-expression and cultural communication, combining visual art and poetry. Mixing and generating poetry based on users input messages is the major feature of this system, which transforms the users into experiencing the state of being a poet. An installation of Poetry Mix-up is shown in Figure 6.5.

In Poetry Mix-up users can send an SMS text to the system, after which it will respond with a rehashing of the submitted SMS text in a poem-like style. This is displayed on a large display for all to see. An installation of this system can be found in the Singaporean-based Kent Ridge MRT station.

In the context of interactive analog-like and digital-like media, in Poetry Mix-up the generated poems that are finally displayed to the public are stored in a database.

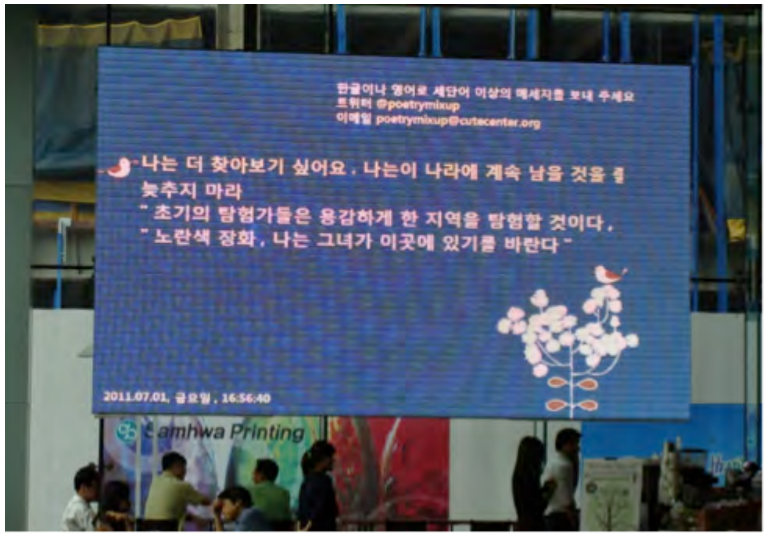

Figure 6.5: Poetry Mix-up demonstrated at Art Center Nabi in Seoul, South Korea in 2011.

Therefore, the stored poems are not bound to any specific media, such as workstations, displays and messaging devices. In addition, the poem is generated in a set of discrete steps using natural language processing, and mobile communication devices mediate the interaction. Therefore, we can argue that Poetry Mix-up is a digital-like interface.

Confucius Computer [14] is a new form of illogical computing [126] based on the eastern philosophy of balance and harmony. The system enables users to have meaningful chatting with a virtual Confucius, as shown in Figure 6.6, to explore the Confucius philosophy, and even solve personal problems on occasion. Similar to Poetry Mix-up, it employs extensive advanced information retrieval and natural language processing techniques.

Confucius Computer's primary function is that of a chatterbot [2]. Users interact with it using a traditional keyboard and mouse interface. Users can have conversations and ask Confucius Computer various questions and it will respond using a database of Confucian edicts, providing esoteric or sometimes seemingly illogical answers so as to instigate creative interpretation by the human user.

[2] A chatter robot is a type of conversational agent, a computer program designed to simulate an intelligent conversation with one or more human users via auditory or textual methods.

Figure 6.6: A screenshot of the Confucius Computer chat interface.

Therefore, Confucius Computer shares similar characteristics with Poetry Mix-up. It does not attach to any special hardware, and is available online. The virtual Confucius generates a related reply from analects in a series of discrete steps. As well as being mediated by the traditional computer interface, Confucius Computer can be also categorised into digital-like media.

6.4.3 Hybrid-like Relationship Between User and System

In this section we discuss projects with hybrid-like characteristics by looking at the Metazoa Ludens and Age Invaders projects.

Metazoa Ludens is a revolutionary system that enables humans to play computer games with small animals in a mixed reality environment [134]. In this system as shown in Figure 6.7, the human user controls a movable robotic arm through a virtual reality game where the robotic arm is represented as a human avatar. The virtual reality game is not bound to any special computer, and is mediated by the keyboard interface. On the other hand, for the pet user, within the large running environment, it chases freely and continuously after the robotic arm and the pet itself is the content and the media during the interaction, as its body is captured and recognised by the

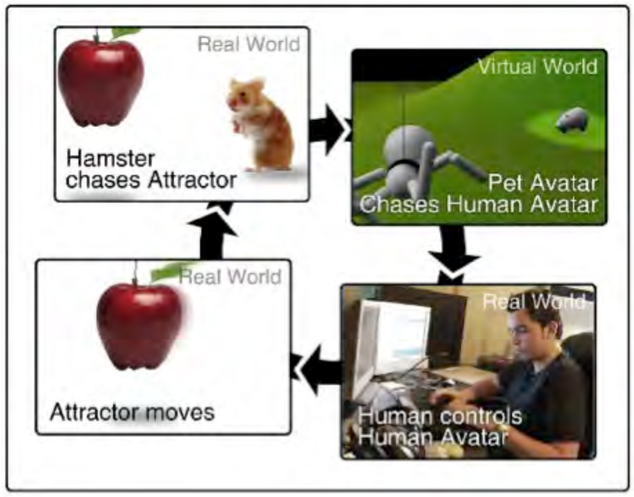

Figure 6.7: Hamster-Human interaction in Metazoa Ludens.

Figure 6.8: Elderly users of the Age Invaders interactive, physical game system.

camera. In addition, based on the user study of the desire for pets to play this system, the pet hamster showed great interest in chasing the physical robotic arm. Therefore a mixture of both analog-like and digital-like characteristics is shown, which makes Metazoa Ludens a hybrid-like interactive system.

Age Invaders (Figure 6.8) is a novel, interactive, intergenerational, physical game that allows the elderly to play harmoniously together with children in physical space, while parents can participate in the game play in real-time through the Internet [72].

The Interface is Intuitive	Interaction is Continuous	Content and Media are Singular in Embodiment	System	Content and Media are Dichotomistic in Embodiment	Interaction is Discrete	The Interface is Mediated
X	X	X	Living Media			
X	X	X	Huggy Pajama			
			Poetry Mix-up	X	X	X
			Confucius Computer	X	X	X
X	X		Metazoa Ludens	X		X
X	X		Age Invaders	X	X	X

Table 6.1: Summarisation of project analysis in the context analog-like and/or digital-like interaction.

With the similar features of mixing physical reality and virtual reality as found in Metazoa Ludens, users can perform free and continuous play with their body using gestures and movements on the interactive floor, which senses the user′s positions. Other users can also interact with players on the computer screen in virtual reality. Therefore, Age Invaders provide a hybrid relationship between users and media.

In summary, Living Media and Huggy Pajama fulfill all the features of analog-like media while Poetry Mix-up and Confucius Computer fall into the digital-like media category. Metazoa Ludens and Age Invaders provide a hybrid-like media experience for the user. Therefore, we can use the characteristics for analog-like and digital-like interaction to analyse and exam all interactive systems. This can also be used to develop digital-like only interaction (interactive digital media), or analog-like only interaction (interactive analog media). The analysis of case study projects is summarised in Table 6.1.

6.5 The Analogness-Digitalness Continuum

Similar to the Virtuality Continuum concept proposed by Paul Milgram and Fumio Kishino [105], the *Analogness-Digitalness Continuum* (or ADC) attempts to describe the continuous relationship of attributes in an interactive system, which could embody any combination of digital-like to analog-like qualities as described in the previous section, Characteristics of Systems with Analog-Like and/or Digital-Like Interaction. The ADC is meant to encompass not just the type of interaction an interactive system provides, but also the method of the embodied relationship between system and user. It therefore differs from other continuums in such that it not only represents the external world, as does the Virtuality Continuum describes, but also the intimate relationship of person and machine. The ADC can therefore be utilised with any HCI implementation when concepts of embodiment and human-factors are involved.

The main motivation to create such a method of classification is two-fold. Firstly, the ADC in of itself can be used to study and classify all interactive systems. Secondly, the ADC in conjunction with the proposed characteristics found in this manuscript can be used to direct development of such systems in order to achieve particular styles of interaction and user/system relationship.

As depicted in Figure 6.9, the ADC offers two polarising dichotomies. On one end is the Analog descriptor. This represents systems with completely analog-like relationships with the interacting user. On the other extreme, completely digital-like interactive relationships between the system and user are represented. Varying scale points between both positions qualify a systems interaction as hybrid. Depending on how analog-like versus digital-like a system interaction could be would govern its tendency to lean towards a particular polarity on the scale. Discerning the position is measured by scoring a system in relation to the proposed rules, as described by the characteristics of analog-like and/or digital-like interaction, previously presented in this chapter.

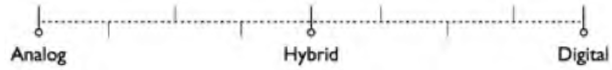

Figure 6.9: The Analogness-Digitalness Continuum (ADC).

6.6 Description of the Analogness-Digitalness Continuum Tool and its Use

The *Analogness-Digitalness Continuum Tool* is a method to situate projects, in regards to the nature and characteristics of the relationship between user and system. It provides a visual means to understand the intensity of a system's *Analogness* or *Digitalness*, depending on a project's disposition towards either end of the scale.

In order to use the tool, the following steps are required.

Step 1: Draw a scale with the headers *Analogness* and *Digitalness* at opposing ends. At the centre of the scale, mark a point. This point denotes absolute *hybridness*. Plot equally measured points between the centre and polar points on both the *Analogness* and *Digitalness* bisections. This equates to two points equally spaced out on the *Analogness* bisection, and two points equally spaced out on the *Digitalness* bisection, one point for each characteristic, including the absolute point for *Analogness* and *Digitalness*, as outlined in the section above titled *Characteristics of Systems with Analog-like and/or Digital-Like Interaction*, and not counting the *Hybrid* characteristic, as it will act as the centre, pivot point. This scale will act as the *Analogness Digitalness Continuum*. This is illustrated in Figure 6.10.

Step 2: Identify the project or projects that you would like to measure using the ADC (Figure 6.11). The selection of multiple projects can give one an understanding of the interrelationship between projects.

Step 3: Using the characteristics described in the section above titled *Characteristics of Systems with Analog-like and/or Digital-Like Interaction*, score each project by whether they fulfill each characteristic. Working through the list of characteristics

Figure 6.10: Prepare an analysis work area by drawing an *Analogness-Digitalness Continuum* (ADC).

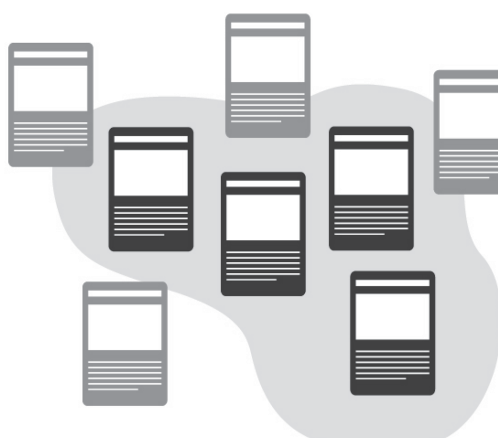

Figure 6.11: Identify the selection of projects to be assessed.

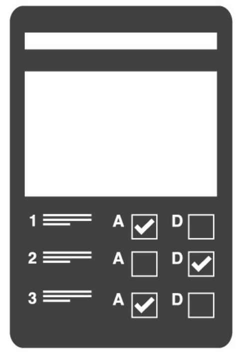

Figure 6.12: Score the selected projects using the Characteristics of Analogness and Digitalness.

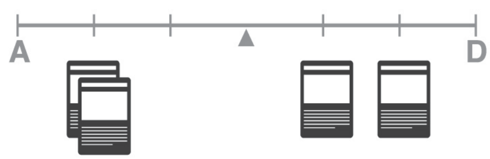

Figure 6.13: Based on whether or not a project fulfills the Characteristics, situate the project on the ADC. Score multiple projects to understand their relationship with one another in accordance with their position on the ADC.

and starting from the centre point, move the project plus or minus a step towards either end of the continuum for each characteristic it fulfills. This is shown in Figure 6.12.

Step 4: Once the list of characteristics has been exhausted, and excluding the 7th, *Hybridness* characteristic, the project should fall at its final position on the continuum (Figure 6.13). In most cases every project measured on the ADC should be a hybrid of some sort. The leaning towards *Analogness* or *Digitalness* is what should be noted.

Step 5: Repeat steps 3 and 4 to plot multiple projects on the ADC. This will create a matrix of projects where one can derive the interrelationship of multiple projects.

Step 6: Once the analog-like or digital-like characteristics have been decerned, systems can be re-evaluated depending on the desire to make an interaction more analog-like or digital-like in nature by using the described characteristics as design guidelines.

6.7 On Interactive Analog Media

By clearly defining what it is for an interface to have notions of *analogness* and *digitalness*, a sub-field of interactive media has emerged. By taking the characteristics of *analogness* and *digitalness* into account when developing interactive systems, interactivity of a purely analog-like nature can now be specifically designed. From this point we propose a new area of research; that of one that takes into account the *analogness* of interactive systems in order to develop truly continuous and intuitive interfaces that are wholly one with the user and the data it presents as a singular embodiment (Figure 6.14).

In an era where media has increasingly become digital, the desire for analog-like interaction with the world around us becomes more desirable. We hope that the

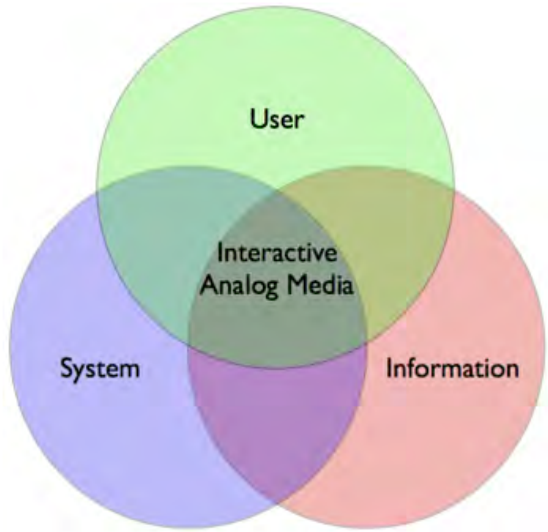

Figure 6.14: User, system and data as a singular embodiment.

proposed field of IAM will elevate ubiquitous computing as a mainstay for human-computer interaction in our everyday lives.

6.8 Discussion

In this chapter we presented characteristics in which relationships between users and interactive systems can be defined and developed, possessing aspects and characteristics of *digitalness* and *analogness* with specific regard to the relationship and embodiment of the user and system. This was achieved by first discussing theories of embodiment from a philosophical perspective in a previous chapter, and how it could relate and be integrated with computer science and engineering by defining what it is for data to be digital or analog.

We then attempted to integrate both concepts into a new definition of analog-like and digital-like interactivity with the presentation of characteristics for interactive analog-like and digital-like media through the analysis of prototypical examplea of interactive systems.

We further supported these characteristics by analyzing published research projects from the Keio-NUS CUTE Center in the National University of Singapore as case studies, and categorized each project in relation to this.

We then go on to present the *Analogness-Digitalness Continuum* (ADC) in order to easily plot and classify interactions between user and system depending on their *analogness* or *digitalness*.

Lastly, we propose a new field of research that looks to develop the *analogness* of interactive systems called *interactive analog media* (IAM).

Chapter 7

Implementing: The Linetic Liquid Interface System

We present an OUI that combines Hall effect sensing and actuation through electromagnetically-manipulated ferrofluid using the IC^{2}MI toolkit proposed in the afore outlined dissertation. The movement of magnets worn on the fingertips, over a surface embedded with a Hall effect sensor array and electromagnets, gives the user the ability to interact with ferrofluid. This system provides a three-dimensional, physically animated response, as well as three-dimensional, spatial-sensing inputs. The vibration of the magnets worn on the fingertips, produced by the repulsing polarity of the electromagnets, provides the user with haptic feedback. Linetic is a multimodal interface with a visual, audio and haptic experience. In this manuscript we explain the overall system from a technical and usability viewpoint by outlining significant experiments conducted that contribute to the development of the system. Furthermore we discuss the philosophical and aesthetic implications of the Linetic system, as well as characterise Linetics disposition to *Analogness* or *Digitalness*.

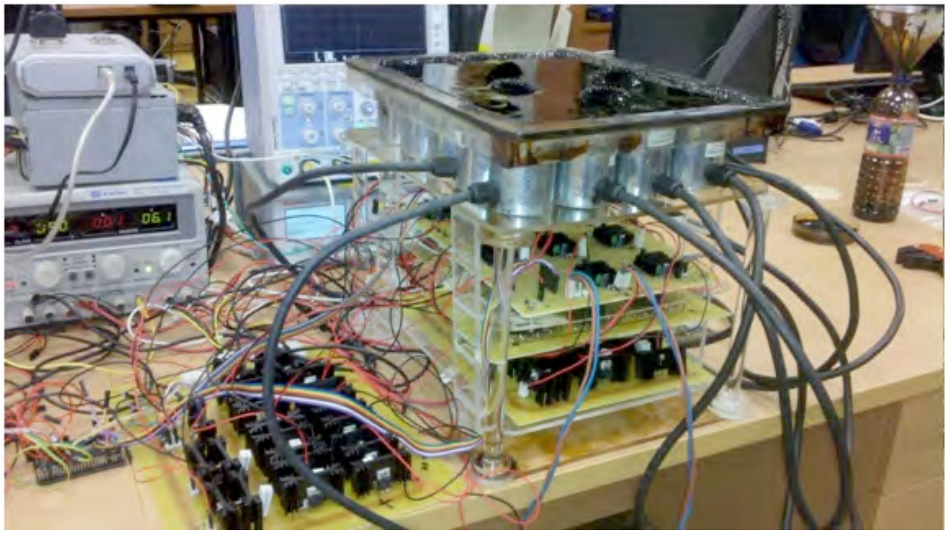

Figure 7.1: Version Alpha of the Linetic system.

7.1 Introduction

Recent progress in HCI has paved the way for a new body of research known as Organic User Interfaces (OUIs) [20] [63]. This field focuses on the need to further explore possibilities for interactive user interfaces using the advances made in electronics and material sciences [62]. OUIs are defined by three factors: the input interface and output display should be one, and the same; the form of the object should change continuously and correlate directly with the function it embodies, and finally the function performed by the object depends on how the physical shape of said object is changed [61].

OUIs open a path to morph the shape and form of the actual computer interface itself. The interface can now be a piece of fabric, a plastic card, liquid, sand, clay or any other material. OUIs enable users to interact with the interface by manipulating the natural qualities of these materials such as bending, stretching, pulling, stroking, etc. This new paradigm moves away from the traditional approach of metaphors and physical objects as defined by tangible user interfaces (TUIs), and explores next generation interfaces focused on the analog, continuous and transitional nature of physical reality and human experiences, as Schwesig points out [124].

With advances in technology pushing the boundaries in regards to the materials used to create ubiquitous interactive systems [149], it is now possible to expand the computer into the everyday environment through softer, and flexible formats [20]. Using these materials and technologies, this chapter presents the implementation of an innovative OUI system based on liquid. This interface explores the potential of liquids as an interface and display device, where the manipulation of liquid becomes both the input and output device. Linetic can provide the user with a natural and organic experience where three-dimensional, tangible interaction takes place.

Building on the idea of a ferrofluid display created by Sachiko Kodama [76], Linetic provides an input/output solution based on ferrofluid. Ferrofluid is essentially a liquid that reacts to magnetic fields. The system is composed of a pool of ferromagentic liquid combined with a sensing and actuation mechanism. The sensing uses an array of Hall effect sensors that measure the density of a magnetic field, while actuation is produced by an array of electromagnets. Sound generation using a MAX/MSP patch running on a connected server augments the output experience.

Wearing a set of magnetic rings, the user can interact with the ferrofluid. The magnetic ring position is detected by the array of Hall effect sensors, which in turn actuates the electromagnets and the sound server. The magnetic field of the active electromagnets produces the morphing of the ferrofluid to create transitional sculptures in conjunction with the gesture, which then generates a sound. At the same time the pulse of the matching polarity electromagnets produce a force feedback vibration on the rings, giving the user haptic feedback.

Through natural movements of the hand, the interface is able to morph from a two-dimensional surface to a three-dimensional form fluidly and dynamically. Using the morphable quality of ferrofluids, we were able to study how liquids could become a novel form of OUI. In sum Linetic provide a tangible, multi-touch interface with haptic feedback that produces a real 3D morphing surface.

7.2 Background

Linetic builds on research by both scientists and artists in creating a malleable, three-dimensional, multi-touch interface. Hiroshi Ishii's seminal research in tangible user interfaces (TUIs) offers insight for natural user interfaces in which this project builds upon [62]. Ishii later went on to categorise generations of TUIs, leading to the development of guidelines for the next iteration of user interfaces, know as Organic User Interfaces [61] [63] [146].

Research into the field of Organic User Interfaces is still in its infancy. In 2008 ACM published a groundbreaking collection of essays that collected the works of OUI's pioneering researchers in a special issue of Communications of the ACM. In this special issue, several key authors outlined various aspects and characteristics that make an OUI:

- *Input Equals Output:*

  In the graphical user interface (GUI) there is a clear division of input and output. The mouse and keyboard input actions from the user. Based on those actions, output is generated graphically on the screen. A key feature of OUIs is that a piece of organic light-emitting diode paper, or any potentially non-planar object for that matter, is meant to input actions from the user and also output them onto the same object.

- *Function Equals Form:*

  The form of an object clearly determines its ability to be used as an input. The statement *Function Equals Form* emphasises this dependency on one another.

Holman and Vertegaal [61] argue that these two are in fact inseparable and that it is a mistake to try to deny this in any way.

- *Form Follows Flow:*

  This principle states that it is of utmost necessity for OUIs to negotiate user actions based on context, e.g. the ubiquitous 'clamshell' phone, where incoming calls alter the phone's function when opening the phone during an incoming call.

In regards to the material we chose to use for our input/output interface, the ferromagnetic art installations by Sachiko Kodama provide an aesthetic viewpoint of how the power of fluid and transient shapes can capture the imagination of viewers [76]. In her projects ferromagnetic fluids are used to create organic shapes that change structure dynamically. Adjusting the power of the electromagnets actuates the ferromagnetic fluid. The magnetic field produced by the electromagnets controls the movement of the ferrofluid, producing a visual output. Linetic builds on this work, providing the user with a means to directly interact with the ferromagnetic fluid in the formation of these embodiments, while inheriting the aesthetic and kinetic qualities that Kodama's pioneering works offer.

Other ferrofluid interfaces include SnOil, which is a controllable display that allows the user to interact with ferromagnetic fluids by tilting the display [46]. The display uses a grid of electromagnets to actuate ferromagnetic fluid in selected areas, and a built-in tilt sensor is used to activate the electromagnets. Actuation of the ferrofluid is binary, up or down, depending on the respective electromagnet state. Linetic expand upon SnOil by offering a novel means of interaction with ferrofluid by directly interacting with the material and provides a variable or analog-like state of the actuated fluid, beyond simply a binary or digital-like on/off state.

MudTub by Tom Gerhardt [50] is an intriguing, quasi-OUI that exploits the material characteristics of mud as an input material, but fails to follow the contemporary definition of OUIs as outlined by Holman and Vertegaal [61], in the sense that the interface medium and output display are not entirely the same. MudTub uses projection to augment the output and provide input. While offering a morphable computer interaction material in the form of mud is novel, our implementation offers more fluid-like properties, a higher degree of controllability, adheres to the tenants of OUIs as outlined by Holman and Vertegaal, and is not nearly as messy.

MudPad [66] is a haptic multi-touch input device that is malleable and can be controlled for localised haptic feedback. It acts similar to Linetic but the materials and methodology of actuation are different. The interaction material is also contained within a bladder and users do not directly interact with the material. Linetic offers the user direct interaction with the display and input material, making it a more compelling example of an OUI.

Hydraulophone [95] is a water-based musical instrument. Users place fingers on jets of water to produce music. Touted as a *Flexible Limitless User Interface*, Hydraulophone resembles a flute, but uses water as opposed to air to produce sound. The Linetic project looked to this as an example of how fluid dynamics could be used for interaction, especially pertaining to the production of music.

Programmable Blobs [148] is a compelling example of a user interface that uses malleable, programmable matter. It differs from Linetic in that it still uses a quasi-solid material compared to the much more fluid attributes of ferrofluid in the Linetic system. Latency during transformation of the Programmable Blobs is also much slower when compared to the speed of Linetic.

All the examples discussed above provide an invaluable and important basis for the research conducted for Linetic. Linetic attempts to expand the field of TUIs beyond solid and static-shaped object manipulation, bridging the gap between physical user actuation and animated representation into a unified input/output device.

7.3 Directing Linetic Development Using Elements of the IC^{2}MI Toolkit

In parallel to the description of OUIs as an extension of tangible user interface research, the IC^{2}MI toolkit was used throughout the development process as a framework to develop interactivity. Using the first three methods described in IC^{2}MI, we identified the area of research that would benefit both our own personal goals as researchers, as well as the work of the lab in which the Linetic system was developed. Using the genealogical tool derived from the *Genealogy of Mixed Reality Lab* projects, we conceptualised the project using the *Blue Sky Innovation* [15] method, and we conceived the interaction model using characteristics of *Analogness* and *Digitalness* [81].

In specific regard to Linetic′s analog-like and digital-like interaction qualities, we used the following characteristics to describe the final system:

- *Analog-Like Interactive Systems: Content and Media are Singular in Embodiment*

  We wanted the interfacing medium (ferrofluid) to act as both the representation of data as well as the media in which the data was embodied in. In order to interact with the system, ferrofluid bubbles needed to be actuated. Likewise though this actuation, the media itself would change shape to provide a new set of information for the user. Because of this, content and media are therefore singular in embodiment.

- *Analog-Like Interactive Systems: Interaction is Continuous*

  As Linetic was conceived to be an interface for creativity and to spark imagination, we wanted the interaction method to be a continuous experience. To use the system, one would need to wave their hands above the surface in order to use the system. Therefore the interaction is not discrete (digital-like) but continuous (analog-like).

- *Analog-Like Interactive Systems: The Interface is Intuitive*

  The data or information that the Linetic system provides to the user is abstract. As an art piece or interactive sculpture, there is no right or wrong way to use it. Users are free to create whatever they desire by simply using there hands and waving them over the surface of the ferrofluid. Because of this simple interaction, Linetic qualifies as an intuitive interface, as the user study contained below shows.

The characteristics applied to the development of the interactive elements of Linetic as described above are affordances that were consciously implemented to provide an interaction that was more analog-like in nature. By counting the amount of characteristics that lean towards *analogness* and the complete lack of *digitalness* characteristics, Linetic qualifies as an entirely analog-like interface, and is neither a hybrid-like or digital-like interactive system, as scored using the *Analogness-Digitalness Continuum* [81].

7.4 System Description

A system diagram is shown in Figure 7.1 and the complete Linetic system is shown in Figure 7.1. By moving fingers over the ferrofluid bubbles, users can manipulate shapes in the liquid in order to interact with the system. The system identifies a magnetic flux change when a finger moves perpendicularly and vertically in relation to the surface. The flux change is detected by the Hall effect sensors embedded beneath the surface of the ferrofluid, which senses the magnetic field produced by the magnets worn on the fingers. In turn, an electromagnet also contained beneath the surface of the ferrofluid is activated and produces a field in which the ferrofluid reacts to, producing a ferrofluid button. The distance between the finger and the ferrofluid

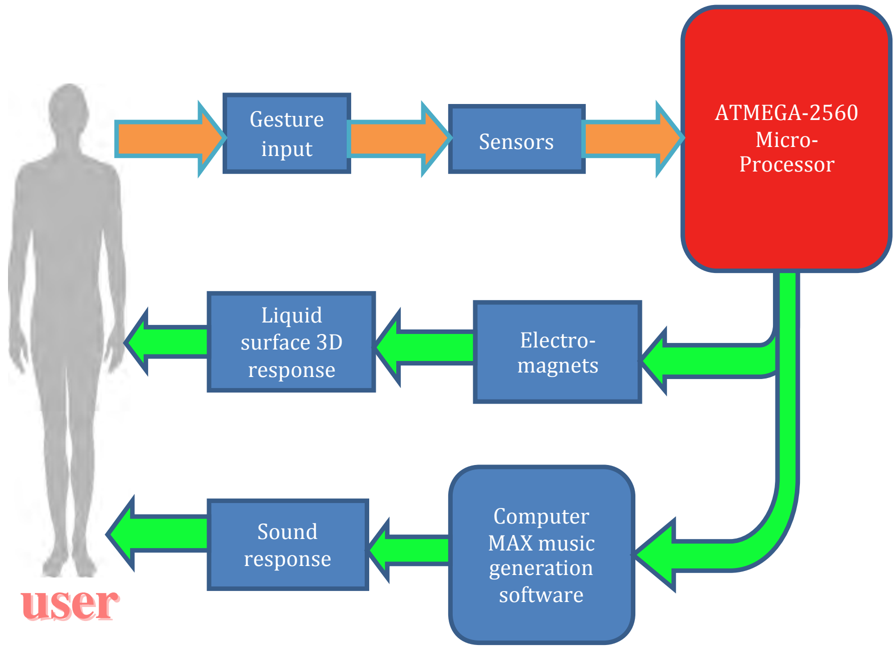

Figure 7.2: A System diagram of the Linetic system.

button is mapped to the pressure and intensity of the click. Haptic feedback is felt by the user through the natural vibrations of the magnet worn on the fingertips.

In the following section we will describe both the hardware (sensing and actuation) and software design of the system in detail. In essence, the Linetic system consists of a set of controller circuits to control the flow of the current, an array of Hall Effect sensors to detect user interaction, an array of electromagnets to actuate the ferrofluid, a ferrofluid pool, a MAX/MSP sub-system for sound generation and a software application programming interface (API).

7.4.1 Hardware Design

In the following section, we will outline the various hardware sub-systems of the Linetic system. Hardware sub-systems include the sensing method, the actuation accessory, the electromagnetic array and circuit.

Sensing

The hardware for sensing is performed by magnetic Hall effect sensors manufactured by Hamlin Electronics[1]. Hall effect sensors measure the density of a magnetic field. The sensor produces an analog output when it is under the influence of any magnetic field. The sensor output is connected to the analog-to-digital converter of the micro-controller used. The sensor is placed directly on top of each electromagnet while the user's hand carries a powerful neodymium magnet with like poles of each magnet facing one another. When the electromagnet is turned on, the sensor output becomes fully saturated. If a neodymium magnet of the same pole is brought close to the surface, the sensor output drops and this is detected as the presence of the user's hands. Voltage drop of the sensor is dependent on the strength of the external magnetic field. Therefore, a sensor voltage drop is much higher when the distance between the finger and the ferrofluid display is reduced. This measurement is used as an input to control the height of the spikes, which are a product of the system.

Actuation Accessory

The actuation of the system, as seen in Figure 7.3, takes place when the user moves their fingers across the ferrofluid surface while wearing a magnetic finger accessory. To design this accessory, we looked at various accessories musicians wear on their fingers, such as guitar picks, to give us ideas on how to best design an accessory that acted as a natural extension of the finger. Fel [40] suggests that for a user to have an aesthetic experience with a system, they need to develop an intimate relationship with the object. One of the ways in which to achieve this relationship is for the user to embody the object. The ring allows for this embodiment of the system where the system becomes an extension of oneself comparable to how a calligrapher uses a paintbrush. The system becomes a tool in the hands of the user. Achieving this kind

[1] Hamlin Electronics (http://www.hamlin.com/)

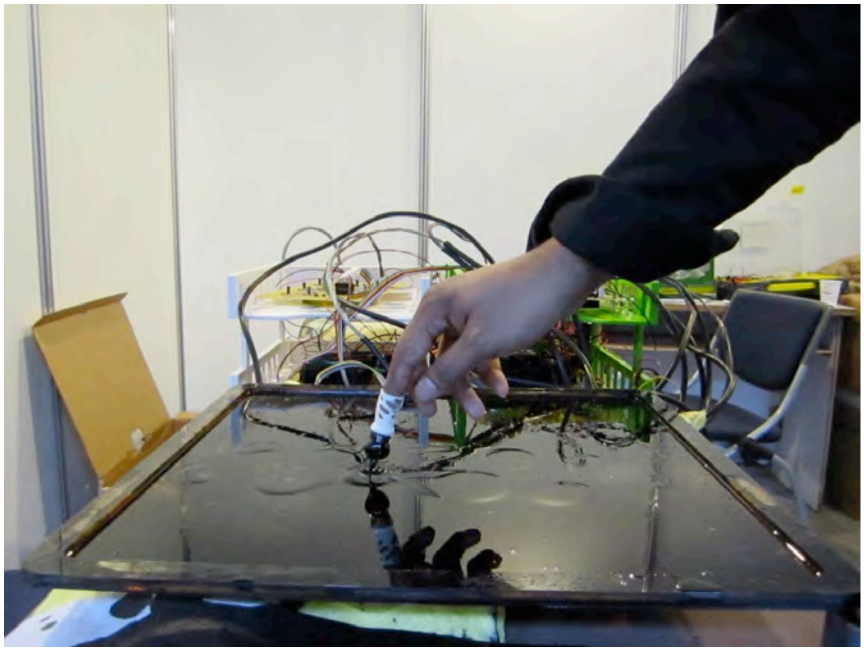

Figure 7.3: Interacting with version Beta of the Linetic system using the wearable accessory.

of interaction was important for us so we decided to design a ring that allows the users to wear and play with the system as opposed to holding a wand and waving it over the surface, as found in previous iterations of the system.

We designed a ring that could be worn on the index finger of each hand. Figure 7.4 shows some of the design iterations. The rings contain a magnet that allows users to actuate the ferrofluid through natural gestures and finger movements. The ring has a cylindrical base made of plastic with a metal, coned shaped tip containing a magnet. When the users play with the system, they can sense a subtle haptic feedback through magnetic repulsion. This enables users to judge the distance they are from the liquid surface without touching it. This is important since when the user gets too close to the fluid, the liquid will get attracted to the metal cone. To avoid this, the haptic feedback enables the user to use the fluid interface without getting wet or stained fingers. Furthermore, electromagnet polarity are configured in such a way as to repel

Figure 7.4: Design iterations for wearable component.

the magnet on the user's finger, once again subtly directing the user to not place her hands too close to the fluid.

Actuation

The screen consists of ferrofluid placed in a shallow acrylic container. This container is placed on top of an array of electromagnets. These electromagnets, when turned on, actuate the fluid, causing it to form bumps and/or spikes depending on the strength of the magnetic field produced. The system is powered using an array of ATX power supplies. These power supplies are then fed to a current limiting circuit. The output current from the current limiter circuits is distributed to the magnet driver board consisting of full-bridge drivers. By feeding the micro-controller's pulse-width modulation (PWM) signals to the magnet drivers, the electromagnetic field produced by the electromagnet array is controlled. This electromagnetic field creates spikes in various shapes and sizes on the surface of the ferrofluid display.

7.4.2 Software Design

In the next section, we will outline the various software sub-systems of the Linetic system. Software sub-systems include the Linetic OUI Framework, sound generation and the circuit firmware.

Linetic OUI Framework

One of the objectives of the research is to develop a software framework for the project. It consists of a system background service and a Java API extension. The framework hides the complexity of the overall hardware and low-level software code from the developer and provides a convenient way to plug different sub-systems into the Linetic system. Therefore the Linetic system could be configured as a tangible input device, a tangible display, or perform both operations to an external system simultaneously. Various kinds of external systems could communicate with the Linetic system through the Linetic OUI framework API.

Sound Generation

In this application we attached Linetic to an instrumental music generation program developed in the MAX/MSP environment. The Max/MSP patch that is used detects incoming signals from the framework and activates appropriate midi piano keys to create sound.

Circuit Firmware

The circuit firmware is written in C and programmed into the micro-controller within the circuit. It communicates with the PC through USB interface and receives information regarding ferrofluid actuation patterns. According to the given information, it dynamically actuates the ferrofluid and creates dynamic patterns in the ferrofluid display by changing the current of the electromagnet grid underneath the ferrofluid container.

7.5 Experiments and Results

Ferrofluid is a special kind of liquid that is influenced by magnetic properties. This liquid is a solution of nano-scale ferromagnetic particles in oil. When approached by an external magnetic field the ferrofluid morphs, its shape resembles spikes on the surface of the liquid. This effect is known as the Magentoviscous Effect. The ferrofluid forms spikes along the magnetic field lines when the magnetic surface force exceeds the stabilising effects of fluid weight and surface tension.

Our previous work includes a series of experiments to measure spike height versus current, distance of two adjacent spikes, transient state of the system and the static linearity of the system [79]. These experiments have demonstrated the linearity of the control mechanisms of the system. Since magnetic systems are highly nonlinear, this system represents a significant step in controlling ferrofluids. The following experiments explore the control mechanisms of the system.

7.5.1 Experiment 1: Hall effect sensor reading versus vertical distance

The point of this experiment is to understand the Hall effect sensor readings in relation to the vertical distance of the actuator (in this case, the finger-worn actuation ring) from the surface. This experiment has been conducted using a Hall effect sensor and an electromagnet, which generates an average flux density on the surface from 450 to 1950 Gauss for the range of 6V to 24V with 1.9 to 7.5 A of electrical current. In the experiment we kept the power of the electromagnet at a constant voltage of 10v and a driven current of 2.44A, with the sensor on the vertical axis on top

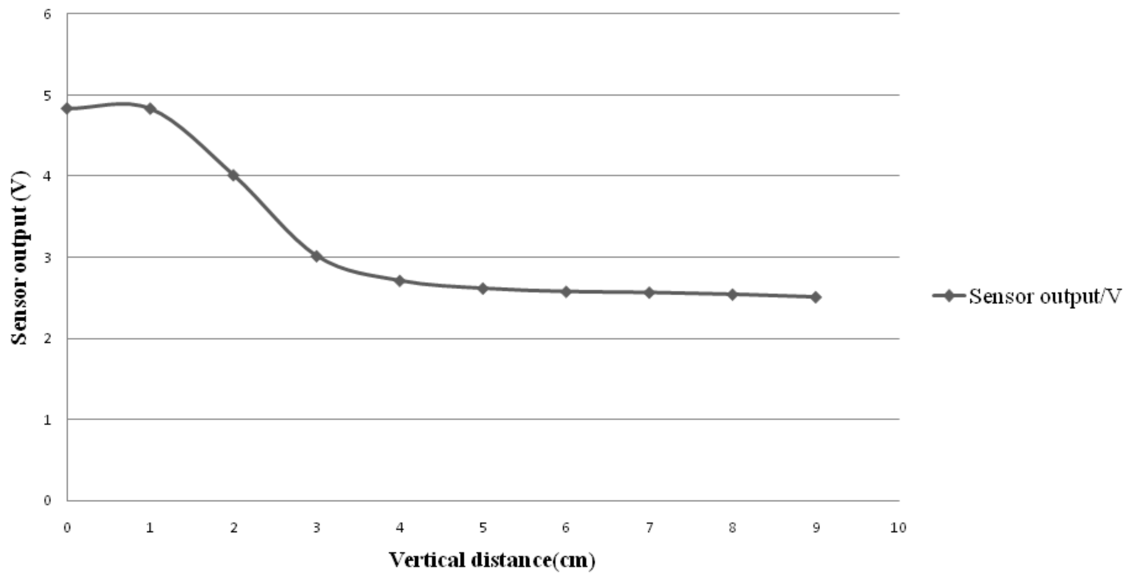

Figure 7.5: Sensor output versus vertical distance.

of the electromagnet. The sensor reading is measured versus the distance to the electromagnet. The value of the sensor output voltage taken is the mean value in one second.

The plot show in Figure 7.5 shows that the sensor is most sensitive with respect to the vertical distance from 0cm to 3cm. When the distance is greater than 3cm, the change in output is much lower. At larger distances, for example the values of 6cm and 7cm, the difference in voltage is only 0.011 volts. However such a small voltage difference is not detected by the micro-controller used for this iteration of the system. Therefore, the sensor cannot detect motion from 6cm to 7cm, but it can detect longer distance motion, e.g. moving from 6cm to 8cm.

7.5.2 Experiment 2: Hall effect sensor reading versus horizontal distance

This experiment is similar to this first experiment, but looks at horizontal distance as opposed to vertical distance. Once more keeping the power of the electromagnet

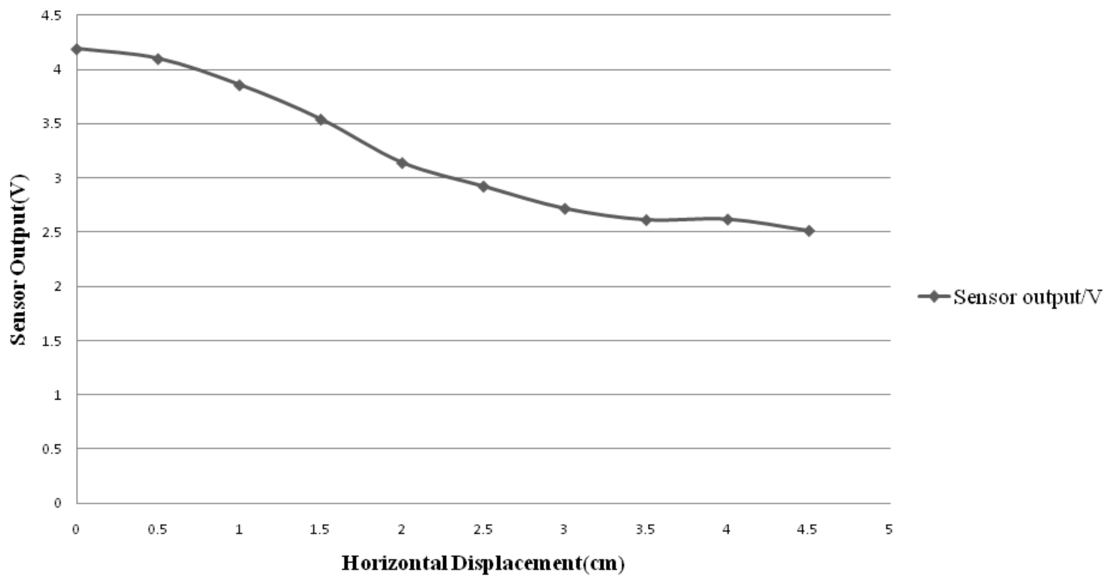

Figure 7.6: Hall effect sensor output versus horizontal displacement.

constant, the sensor is placed on the vertical axis of the electromagnet at 2cm, since at this distance the sensor is most sensitive, registering the largest change in values with respect to distance moved. An oscilloscope was used to measure the voltage output of the sensor. The sensor reading is measured against the horizontal distance to the electromagnet. The value of the sensor output voltage taken is the mean value in one second.

In this experiment the change of driven current is also recorded. After the conducting of Experiment 1 the electromagnet temperature increases, which in turn affects the driven current. Driven current will be used as a reference of the change of power of the electromagnet as the power of the electromagnet is directly proportional with the current. Due to this phenomenon, it is easy to compare the result by making a scaling.

This experiment has been conducted using the following settings:

Zero magnetic field value: 2.490V

Electromagnet driven voltage: 10v

Diameter of the Electromagnet: 5cm

The value of the sensor output voltage taken is the mean value in one second.

The plot in Figure 7.6 shows that the sensor voltage is close to 2.5 volts (zero field voltage) after 3.5cm of displacement. Experiment 1 shows that the resolution of the system cannot distinguish any smaller changes. Within 0.02 volts, the magnetic field at 3.5cm and beyond are too small to cause a change in the microprocessor. This experiment shows that the magnetic field out of the horizontal area of the magnet is too small to be detected at the optimal vertical distance. This is advantageous for the system since the tracking system gives an almost perfect horizontal reading without external noise from the neighbouring magnets.

7.5.3 Experiment 3: Characterisation of magnetic Hall effect sensor readings under the influence of multiple fields

In this experiment the readings of the Hall effect sensor are measured to determine the influence of the magnetic fields generated by the electromagnets and neodymium magnets. These readings will provide the correct parameters for the microcontroller firmware. Previous experiments have shown that the optimum position is to place the sensor such that the readings are minimally affected by the electromagnet, while still being close enough for the sensor to be associated with the electromagnet, and in a position such as to be able to detect a neodymium magnet above its surface. This position is right next to the electromagnet, level with the top surface of the magnet.

Under these conditions, the sensor shows slight changes in readings when the electromagnet is turned on. The goal of this experiment is to determine which combinations of the two magnetic fields (electromagnet and neodymium) cancel one another, making it impossible to detect the position of the hand.

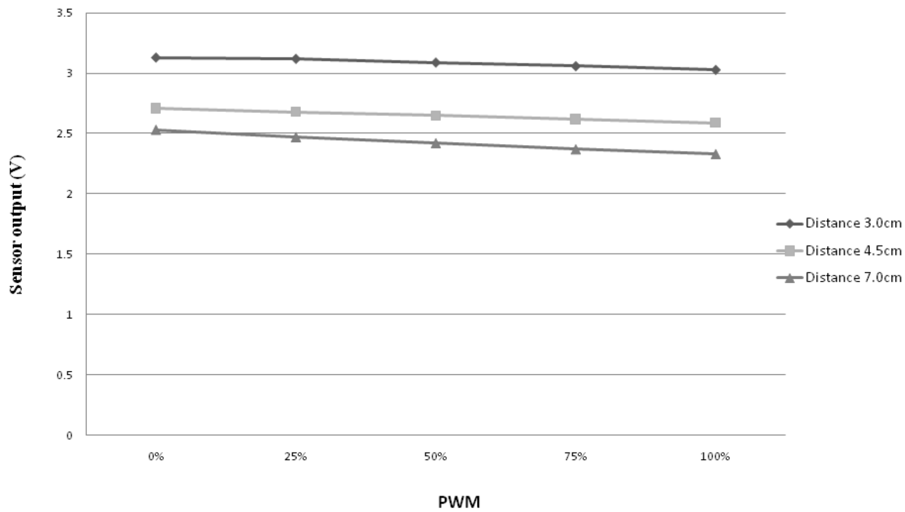

Figure 7.7: Sensor reading values obtained for different distances versus PWM.

The electromagnet is connected to a power supply, supplying 10V and up to 2A of current. Its output magnitude is controlled by a PWM input to the driver circuit. It is positioned such that the field of the North Pole is directed vertically upwards and the South Pole vertically downwards.

The sensor is supplied the rated of 5V and is positioned such that it is in level with the top of the electromagnet and directly next to it. Its output is connected to an oscilloscope. A non-magnetic material at varying heights directly above the sensor holds the neodymium magnet. Its pole direction is fixed, with the South Pole facing downwards.

The reading of the steady-state output voltage of the sensor is recorded using the oscilloscope, while varying the height and direction of the neodymium magnet and the PWM input to the electromagnet.

First the default sensor value is taken. Without the neodymium magnet or electromagnet influence, the reading is 2.50V.

Next, with the neodymium magnet pole at South Pole (facing down), the PWM values and distances are measured.

Here the strength of the electromagnet's field serves to decrease the reading of the sensor, whereas the position of the neodymium magnet field serves to increase the reading of the sensor. This results in a case where the value of the sensor is unable to detect the presence of the neodymium magnet due to the electromagnet's field.

From the data we gathered, this occurs in the case when the distance of the neodymium magnet is 7.0cm. If the electromagnet is off, the reading is 2.53V, but if the electromagnet is turned on, the reading falls below the 2.50V neutral value. To circumvent this problem, we could use like poles instead of unlike poles, i.e. the North side of the neodymium magnet facing the North side of the electromagnet. This causes both magnets to boost each other's readings, which can be compensated for by changing the sensitivity in the software. This approach has the peripheral advantages of preventing the two magnets from attracting each other and preventing the neodymium magnet from picking up the ferrofluid contained on the surface of the system. The findings from this experiment are summarised in Figure 7.7.

7.6 User Interaction Methodology

In regards to the user interaction methodology, we attempted to simulate some interactions that reflect both the aesthetics and playfulness of interacting with fluid. Although the dramatic effects of water as a tactile surface has been previously explored [114], no precedent in regards to the interaction with ferrofluid, which has distinctly different fluid characteristics, has been recorded. Due to this, an adaptation of previous methods as well as trial and error was employed.

Due to the messy nature of ferrofluid as well as the nature of sensing inherent to the system, we decided to employ a finger accessory that allowed users to interact with the fluid without actually touching it. This reduced the methods of interaction to that if simple mid-air gestures, some of which are employed in [5]. These gestures

Figure 7.8: User study participants using version Gamma of the Linetic system.

included waving and tapping. Like-polarity between the surface and fingertip magnets allowed a force resistance that made tapping a particularly compelling interaction.

Later on, we decided to remove the haptic subsystem in order to concentrate on the visual and audio effects of the system. This led us to the Gamma iteration of the Linetic system. With this system, we conducted the following user study.

7.7 User Study and Method

For the Gamma iteration of the system, a preliminary field test was performed in order to better understand the usability and to also inform us on the possible challenges and limitations of studying the usability of such a unique system. We attempted to measure two items with this study. Firstly, we wanted to understand if gender effected the overall success rate users could achieve when asked to perform precise tasks using the interface. Secondly, we wanted to see if the user's performance improved through repetitive use. To find answers to these two question, we analysed task success data recorded by the system during the performance of tasks by the users.

With the display and input functionality of the system in mind, a simple task was designed. Similar to the hardware-based game Simon [107], users were briefed to watch a sequence of ferrofluid buttons activate and were then asked to replicated the sequence in the same order by using the mid-air gesture of pressing. Two practice rounds were allowed before data recording for the study was conducted. Two sequences of three patterns each were played and then mimicked by the user. The success rate of the user performing the task was recorded by the system. Although both a preliminary ethnographic survey as well as a self-reporting style post-task survey were modelled after usability survey examples provided in [119], for this manuscript we felt that the performance metrics were more significant then the self-reporting data and have included only the performance metrics in this manuscript.

7.7.1 Experiment Setup

For the purpose of this user study, the system was configured without haptic feedback. This was done by replacing the normal sensing subsystem of Hall effect sensors with that of camera vision. We also created a new container that covered and housed the ferrofluid. We configured the systems as such in order to make sure that participants would not be stained by the liquid.

Participants stood in front of the system with a researcher monitoring their performance. The assigned researcher would explain the system and task during the practice rounds and would refrain from helping the user during the actual test. The computer automatically recorded the success/failure results of the user during the experiment. Once the test was finished, users were then brought to another researcher manning another station. At this station a computer with a self-reporting survey was presented. Users were then asked to fill out the survey, thus completing the user study. Photos of the user study setup are depicted in Figure 7.8.

7.7.2 Participants

As this preliminary user study was conducted not only to gain an understanding of the usability of the system but to also inform us on the possible challenges and limitations of studying the usability of such a unique system, participants were sourced using an accidental/convenience sample model. Twenty participants (10 male, 10 female) were chosen for the study, consisting entirely of students and staff from our laboratory. Some of these participants are represented by Figure 7.8. Because each participant (mean age=27.8, SD=3.8) works in some way or another within an engineering laboratory as either a researcher, student or support staff, each test subject has had experience participating in studies for the testing of interactive systems. However we did make sure that each participant did not have any experience using the Linetic system. In effect, this was the first time each test subject has used the Linetic system.

7.7.3 Results and Analysis

All data was analysed using StatSoft Statistica and was checked for normality using KolmogorovSmirnoff test for normality and ShapiroWilks W test.

The first result of the experiment is the effect of gender on the number of correctly performed tasks using the Linetic system. Female participants completed on average of 65% of tasks successfully. Male participants completed on average 68.7% of tasks successfully. These statistics are represented in Figure 7.9. An ANOVA showed that gender holds no significant effect [$F(2,20) = 0.18$, $p < 0.6$] in regards to using the Linetic system for the specified tasks.

In terms of learning curve between the first set of three tasks (tasks 1 to 3) and the last set of three tasks (tasks 4 to 6), users performed better during the second set of tasks. For the sum total of all participants, users performed an average of 13.7% better during the last three tasks compared to the first three tasks. An ANOVA

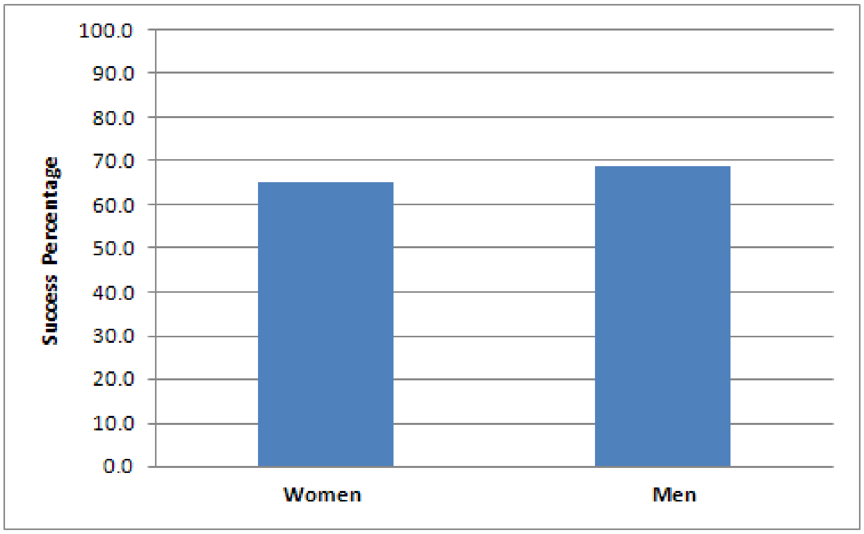

Figure 7.9: Female versus male average overall performance.

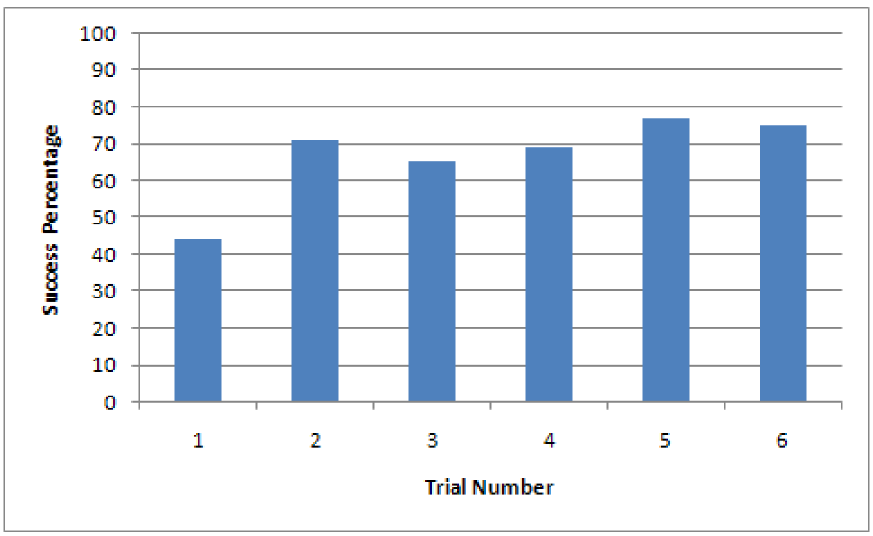

Figure 7.10: Average performance over all six task trials.

showed that performance does indeed improve as users familiarise themselves with the system to significant effect [$F(2,20) = 4.3$, $p < 0.04$] when comparing the first set of tasks performed to the second set of tasks performed. This shows that through familiarisation of the system, user accuracy increased. These statistics are represented in Figure 7.10, with a complete breakdown of performance by all users is represented in Table 7.1.

								Personal Results	
Name	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Accuracy Precentage (trial no 1-3)	Accuracy Precentage (trial no 4-6)	Total Success Precentage
Women 1	0%	100%	20%	20%	40%	40%	40.0	33.3	36.7
Women 2	20%	40%	60%	100%	100%	80%	40.0	93.3	66.7
Women 3	100%	80%	100%	100%	100%	100%	93.3	100.0	96.7
Women 4	0%	80%	100%	100%	80%	100%	60.0	93.3	76.7
Women 5	0%	40%	40%	40%	40%	40%	26.7	40.0	33.3
Women 6	60%	100%	100%	100%	80%	100%	86.7	93.3	90.0
Women 7	40%	40%	40%	80%	80%	40%	40.0	66.7	53.3
Women 8	60%	80%	80%	100%	80%	80%	73.3	86.7	80.0
Women 9	20%	100%	40%	60%	80%	0%	53.3	46.7	50.0
Women 10	40%	80%	60%	80%	80%	60%	60.0	73.3	66.7
Man 1	40%	80%	100%	100%	80%	100%	73.3	93.3	83.3
Man 2	20%	100%	20%	40%	80%	80%	46.7	66.7	56.7
Man 3	40%	40%	60%	0%	40%	20%	46.7	20.0	33.3
Man 4	20%	80%	60%	40%	80%	100%	53.3	73.3	63.3
Man 5	60%	60%	60%	80%	100%	80%	60.0	86.7	73.3
Man 6	80%	80%	80%	80%	60%	100%	80.0	80.0	80.0
Man 7	80%	100%	80%	100%	100%	100%	86.7	100.0	93.3
Man 8	40%	20%	100%	60%	80%	100%	53.3	80.0	66.7
Man 9	80%	40%	20%	20%	100%	100%	46.7	73.3	60.0
Man 10	80%	80%	80%	80%	60%	80%	80.0	73.3	76.7
Women Success Percentage	34	74	64	78	76	64	57.3	72.7	**65.0**
Men Success Percentage	54	68	66	60	78	86	62.7	74.7	**68.7**
Total Success Percentage	44	71	65	69	77	75	**60.0**	**73.7**	**66.8**

Table 7.1: Average performance over all six task trials.

In analysing the data, we learned a number of key lessons. As a system, we found that users were more involved when free-playing with the material aspects of the system then when using the system to perform tasks that required specific accuracy. As a logical information system, Linetic fails to provide the precision that more concrete representational systems provide. We also found that due to the limited input and display capabilities of the system, users could use the system quickly but more complex interactions were not possible. The reason for this is most likely the combination of the simplicity of the metaphors used in the system, as well as the design of the task users were asked to perform. Still even with these limitations outlined by users in the self-reporting survey, users unanimously enjoyed playing with the system despite its technical limitations.

7.8 Aesthetic Interactions with Linetic

Although efficiency and speed are two important characteristics for most technical devices, research suggests that these attributes are not sufficient to fulfil all of a user's needs [36] [82]. Aside from the technical characteristics of the device, a user needs a series of other characteristics that enrich the user experience of an artifact, device or technology. People search for these characteristics that allow exploration and a holistic experience of an artefact instead of just basic features. Through Linetic, we hope to tap into these deeper desires and human emotions in order to be able to produce a more enriching, aesthetic experience of the system. The aesthetic experience refers to the pragmatic aesthetics that Dewey [31] and Shustermann [128] describe, as well as the guidelines that Petersen and others have developed for Aesthetic Interactions [112] [92] from the pragmatist aesthetics viewpoint.

Fels [40] states that for an individual to have an aesthetic experience, there needs to be an intimacy that is built between the person and the object. Fels believes that when people are able to manipulate an object skilfully or intimately, this produces an aesthetic experience. He describes four types of relationships that one is able to have with an object and these are as follows: the person communicates with the object; the person embodies the object; object communicates with person; object embodies the person. Through Linetic we are able to achieve the first three of these experiences: person communicates with object; object communicates with person; the person embodies the object.

First, the user is able to communicate with the system in a direct and natural way through touch. Interacting with the liquid, the user can start a dialogue in which the system responds to the user. The still, dark pool of ferrofluid, with its reflective surface like a black mirror, has the ability to draw people to it in the same way artist Richard Wilson [154] was able to capture the imagination of his audience with his installation 20:50 - a room filled with thick sump oil. According to Khaslavsky et al.

[69], the first step to seducing your audience is to entice them in order to grab their attention. It is the fluid quality of ferrofluid that makes it a material that probes curiosity and encourages play. This curiosity naturally leads to one wanting to touch the liquid and explore it.

The liquid possesses the playful characteristics needed for learning by playing, which is a learning mechanism for most people. The system lends itself to playful exploration and thus a relationship with the system can begin. Unlike a solid tangible interface, liquid has the ability to take the shape of its container and allows for the free manoeuvring of itself. As people move their fingers above the liquid they begin to learn quickly how to sculpt and manipulate the liquid, creating three dimensional, liquid sculptures combined with sound that respond to the users tactile exploration. This seemingly magical quality of being able to sculpt ferrofluid has been the main spark of inspiration that motivates us to exploit this interaction.

When interaction begins the user learns by playing with the liquid, the system responds to the user's actions, producing a sound as well as morphing the shape of the surface liquid. The control and manipulation of the liquid leads to the creation of music. This is the second relationship that Fels describes where the person embodies an object, and the object becomes an extension of the person. Like a pianist and her piano, or a calligrapher and her brush, Linetic can become an extension of the user and as her fingers sculpt the liquid, the arrangement allows a dialog between the user and the system through music and sculpture. The enjoyment of playing in and with water is simulated with Linetic, which transfers this simple level of interaction and extends itself to be an instrument that the user can find pleasure in playing, regardless of the result. The user embodies the system and this increases the level of intimacy that the user experiences with the system.

Aesthetic interaction suggests that the use of the system gives it meaning and creates an aesthetic experience [112], the appropriation of Linetic by the user and the freedom for improvisation makes this a platform for creative expression and meaning-making. Here the user is able to intelligently construct music through the simple and ordinary actions of playing with liquid, making the natural into a magical experience, thus capturing their imagination.

The third way in which a person can relate to an object is when the object communicates to the person; there is no interaction and it is much like how we enjoy a painting. Even at this level Linetic has the ability to engage the audience. The liquid, which seems to have a life of its own, can mesmerise audiences and this quality was evident in the work of Sachiko Kodama. With Linetic, the audience can reach out to the liquid and with the movement of their fingers, can engage with this liquid as a piano player would with piano keys. This allows the user to engage in a more intimate way with the interface as Fels defines intimacy, and allows the user to use this interface as an extension of them.

One of the questions we wanted to address with this project is how we keep the audiences engaged in this experience, and help them to take away a meaningful experience. It was important for us to make sure they left feeling like they wanted to come back for further exploration. We are trying to understand what it takes to continue to capture a user's imagination much like a great piece of music or dance. Music or art that has stood the test of time are examples of work where the creator is able to captivate the audience even after decades from when the work was produced [92]. Many interactive systems today have not yet been able to capture users in the same way. People easily adapt to new technology and once they understand how to use it, it can or frequently loose its novelty. Liquid is a material that people from different disciplines continue to study to understand its powerful effect on our body, mind and beyond. Liquid as an interface for computing opens the possibility of a whole new way of how we understand and engage with the computing world. The exact ways in which we might use liquids as the future button is still to be explored and Linetic is a beginning of this exploration.

7.9 Future Work

Future work for this project involves efforts in several directions: exploration of new materials, new array configurations, improvements in the methodology of gestural interactions and most importantly, the development of relevant applications in order to explore the full potential of HCI using liquids as a medium.

The search for new materials for different effects and increased controllability involves experimentation with materials, such as, electrorheological (ER) and magnetorheological (MR) fluids. These materials will provide another avenue for OUIs and the Linetic project.

Refinement of the electromagnet array is also important so as to create a more fine-grained and higher-resolution display. The use of other magnet arrangements will also enable us to control electromagnetic fields better, so as to create more complex and intricate shapes, which will enable us to explore more real-world applications.

An effort to create a concise library of gestures that are more intuitive for use with the system is also desirable in order to disseminate a methodology in which other researchers can base new research on. Once a concise gestural library is created the project will focus on developing and executing more user studies in order to fine-tune the usability of the system.

Finally an integrated development environment (IDE) for direct programming of Linetic is desired so that the technology can be shared internationally, which can foster application development in the academic and commercial fields.

7.10 Summary

In this paper we describe a new iteration of the Linetic system that uses the Hall effect as a novel form of interaction and actuation. By using Hall effect sensing in combination with a new accessory worn on the fingertips, users avoid messiness and staining, which was a previous downfall of the original system.

We also outline in this paper, three new experiments that enabled us to develop the new iteration of the Linetic system. These include findings regarding the relationship between perpendicular distances of the Hall effect sensor and the magnetic field generated by the electromagnetic array embedded in the surface of the system, the characterisation of the magnetic Hall effect sensor readings under the influence of multiple magnetic fields, and the relationship of distance from the sensor versus PWM.

A preliminary user study was also performed in order to understand the usability of the system, as well as to inform the authors on the possible challenges of evaluating such a system for use as an interface and display device.

Aesthetics influence user experience. In this chapter the aesthetic implications of using liquid as a means for HCI are also discussed. We felt a need to outline these implications in order to accurately prepare for future works that will enable new iterations of the Linetic system.

Finally, we also discuss the addition of haptic feedback facilitated by the vibration of the magnets placed on the fingertips, providing an additional modality of feedback, along with the previously developed modalities of sound and visual output. This new actuation accessory provides a means for users to interact with the Linetic system without the need to actually touch the ferrofluid, and still provides instantaneous tactile feedback.

Chapter 8

Measuring: Considering an Interactivity Index and Hierarchy for Interactive Systems Development

This chapter looks to future methods and considerations in development, which could progress the research presented in this dissertation. This section manifests itself as the *Measuring* method part of the proposed toolkit for experience designers. In one way the toolkit could be extended by providing a synthesis of qualitative and quantitative evaluation methods to further characterise and even rank interactive systems and experiences. The other extension of the work contained in this dissertation is that of a philosophical one, and asks the question of the overall purpose and role of technology, content and semantics.

In the first part of this section, we look towards formulating a means to calculate, measure and rank the level of interactivity for any given interactive system. Using both affective methods of inquiry and quantitative measurements of physiological states, we propose a means to derive an index score. This index score allows a baseline measurement of all interactive systems, which enables the ranking of interactive systems in an *Interactivity Index*.

In the second part of this section, we attempt to address the need for discussion regarding the multidisciplinary work towards the development of interactive artworks, systems and products. By deconstructing the roles of technology, content creation and semantics, we attempt to understand the importance of each in regards to the motivation to develop interactive works.

8.1 Considering an Interactivity Index

As new technologies develop, so to does our relationship with technology. Defining the nature of the interactivity between person and artefact has been problematic. Contention across the disciplines due to lingo and methodologies employed prevents a unifying theory to come of age.

Quantitative methods employed in psychology such as heuristics [93] [158] and affect [9], along with physiological measurements like electrodermal activity [85] have been appropriated and employed by the HCI community as a means of adding quantitative measurements to their research.

Qualitative methods are also widely used by the HCI community to collect data, mostly regarding affect of a system or interaction methodology. One of the most popular means for this type of measurement has been the use of Flow theory [19] [53]. Flow State Scale (FSS) is often employed by researchers to evaluate user experience and affect.

The use of afore mentioned methods of evaluation although widely accepted, still represent a parity gap between these two popular means of measurement in HCI. In this section we propose a synthesised way to bridge this gap, by offering a method that combines affective measurement using FSS with quantitative data derived from physiological measurement. By synthesising both measurements into a unified unit, we offer the HCI community a way to measure and rank interactivity. We call the product of this synthesis the *Interactivity Index*.

8.1.1 Defining Interactivity

In order to provide a synthesis of both FSS and physiological data, we aim to define an equation to identify the contributing factors to interactivity. However before we can do this, a stance in regards to the definition of interactivity must be taken.

The term *interactivity* is contested between several disciplines that include the HCI, information sciences, communication, psychology, design and philosophy fields. For our purposes, we use a contingency view in regards to the definition of interactivity as outlined by Sheizaf Rafaeli. Sheizaf Rafaeli defines interactivity as *an expression of the extent that in a given series of communication exchanges, any third (or later) transmission (or message) is related to the degree to which previous exchanges referred to even earlier transmissions* [116].

He then goes on to propose a hierarchy of computer-mediated communication categorised into three levels: *Noninteractive*, when a message is not related to previous messages; *Reactive*, when a message is related only to one immediately previous message; and *Interactive*, when a message is related to a number of previous messages and to the relationship between them [116].

Although a contingency view, we believe it to be an adequate one when discussing the measurement of interactivity as it provides all disciplines a means to normalise the definition of interactivity.

8.1.2 Flow Theory

Mihály Cskszentmihályis seminal work on Flow theory [24], described in the branch of psychology called positive psychology [125] is a concept that is widely referenced in various fields.

In HCI, Flow theory enables researchers an understanding into the mental state of operation in which a person is engaged with, in regards to their immersion, involvement and feeling of success or failure while engaged with a particular activity [25].

There has been some contention in regards to the suitability of Flow theory and its deployment into HCI research. Finneran points out that there are inconsistencies and a lack of literature when it comes to using Flow, as it is used in computer-mediated environments [44]. Finneran cautions researchers to examine hidden assumptions to the theory when applying Flow to IT related issues and concerns.

In agreement with Finneran, there is a major discrepancy owning to the lack of empirical data when Flow is solely employed as a means for evaluation. The supplementation of Flow with quantitative, physiological data would improve greatly the findings and presumptions researchers make when using Flow as a method for evaluation.

8.1.3 Q-Sensors

Obtaining physiological data has increasingly become easier since the advent of consumer-available measurement equipment. One such device is Affectiva′s Q-Sensor[1]. Q-Sensors are able to record tonic and phasic changes in electrodermal activity, temperature and accelerometer data along the course of a given time. The fact that it can do all of this wirelessly also helps the measurement of physiological data in various situations and environments.

[1]http://www.qsensortech.com/

Q-Sensors provide physiological data that researchers can use in order to collect quantitative data, but this data alone does not provide the quality of affect and user experience that a Flow evaluation provides. With this in mind, a synthesis of both physiological metrics and Flow makes sense when attempting to paint a complete picture of user experience in terms of the level of emersion and involvement when engaged with an interactive system.

8.1.4 Combining Flow State Scale and Physiological Data From Q-Sensors Into a Usable Equation

According to Flow State Scales [139], we have 36 measurable items to indicate the level of Flow. We can use the mean value and the variance of these 36 items to indicate the Flow of interaction, where smaller mean value with smaller variance shows better flow during the interaction. On the other hand, the Interactivity Index depends on the portion of the system latency time over the total interaction time, which shows the reaction speed of the system. Finally, the Interactivity Index is related to the data captured by the Q-Sensor.

8.2 Considering a Hierarchy for Interactive Systems Development

The main protagonist in Roald Dahl′s Charlie and the Chocolate Factory [26], Charlie is faced with a difficult choice between choosing the very tangible benefit of feeding his family with the potential earnings through the sale of his newly discovered Golden Ticket to Arthur Slugworth, or to use his ticket to escape his hardships for a day to tour Willy Wonka′s highly secretive and wondrous chocolate factory. After weighing the potential options, in Charlie′s opinion there is nothing worth more to him then getting a chance to escape the banalities of his everyday life, if even for just a fleeting moment, and even when it means sacrificing a great source of sustenance for his entire family, and ultimately decides to experience a day with Willy Wonka in his factory.

The decision made by Charlie is a fitting metaphor to describe the binary choices we as a community of artists, technologists, researchers and practitioners face. Technology or content [127]? Invention or innovation [130]? Engineering or craft [142]? Aesthetics or functionality [35]? Tangibility or virtuality [105]? Analogness or digitalness [81]? Materiality or immateriality [41]? The question often appears in various forms within the many fields that ultimately make up the new media art, user experience, interaction design, and HCI communities. Is the development of more and more iterative technologies the ultimate means to benefit an audience? Or is the design of content more valuable?

At one point in the narrative of HCI as a developing field of expression, study and practice, the creation of newer, faster, smarter and better technologies seemed to be the means to unleash the human potential. The myth of technology as *The Great Leveller* [97] was adopted by scholars, enterprise and policy-makers alike. As such researchers and practitioners were interested in the development of novel interface technologies and their application. As soon as a methodological breakthrough was made, it was heralded as the future of interactivity. Ubiquitous computing [150], tangible user interfaces [64], affective computing [113], organic user interfaces [60], etc. have become almost biblical in terms of their reverence by the community, and directed most system, content and user experience development.

Yet even with these ground breaking epiphanies in the interactive media research fields, we still use much of the same tools we used to work and play with as we did decades ago. We still type this manuscript on a keyboard using essentially the same metaphors as our precursors did years before [87]. Ishii and Ullmer′s seminal work on tangible user interfaces describes a world where digital data and analog life become one and the same. Yet at the time of this manuscript′s authoring it has been about 15 years since their first work on Tangible Bits [64] was published, and it can be argued that tangible user interfaces are only just now becoming a viable way to interact with technology, though we are still far from the mainstream vision it set out to be.

Technologist soon realised that technology in of itself would not be the solution to all of life's problems. Social scientists, designers and and other creative practices came into the forefront, and with it considerations of the audience, aesthetics and content became important [98].

Technological tools were now being described as platforms. Platforms such as YouTube[2] allowed users to contribute immeasurable amounts of content [39]. Beyond the technology, the management of such content became a critical issue [96]. Along with the management of all this data, more importantly the deriving of semantic meaning from this content is quickly becoming a frontier of innovation. But what does this all mean to the interactivity researcher, creative practitioner and developer?

At the pinnacle of the motivational hierarchy of interactive systems development should be the user experience. More specifically we argue that the curation of technology and content, which enables users to derive meaning, is much more important to the user experience then both technology and content in of itself. Akin to Maslow's Hierarchy of Needs [99] users of interactive systems also have a hierarchy of needs, namely technology at the base of the pyramid, followed by content, with meaning at its apex.

8.2.1 A Hierarchy for Interactive Systems Development

It can be assumed that a successful interactive product, artwork, design or installation requires a multitude of factors to make it succeed. At its absolute base, technology as a platform is needed to facilitate the possibilities of any work. Yet technology is

[2] YouTube (http://www.youtube.com/)

empty unless it is filled with content. Content becomes the fuel to drive a meaningful technology. Without musical data, a compact disc is virtually useless. And even if content is present, this content is meaningless without the adequate semantics to make it at the very least comprehensible to the end user. If a non-Italian speaker attempts to read Dante′s Divine Comedy [3] in the original language, the data that it contains would be meaningless. A parity between data and end user must be reached for it to be communicated.

At the Base of the Pyramid: Technology

From a technological viewpoint, material language plays an important role in the transmission and acquiring of meaning [84]. The semiotics of any piece of technology or material can offer a myriad of semantics. Take the example of silk. In many ways it has a widely different material language when compared to cotton. The material conjures all manner of context including that of ancient Chinese royalty, down to the delicateness of the material when compared to cotton [153]. Likewise does porcelain possess a different semantic and contextual meaning when compared to clay, as does glass when compared to wood, and so forth. It is important for both the creative practitioner and technological developer to consider such contexts as it will ultimately affect the semantics of the final product they aim to develop.

When building new interactive works, we turn to the material language of the physical world, their meanings and contexts, and use them to leverage our interaction. Yet in fields such as HCI, we are still lacking a strong material language/semantics that will enable people to make meaning through the interaction with these interfaces [34].We tend to see new interfaces as novel technology, instead of seeing it as materials to create meaning with. The next generation will see these interfaces as natural and normal, and will be able to see it beyond its *wow factor* to really use it in meaningful ways and to use these interface technologies as materials in their development of meaningful and useful products.

Every year we see more and more novel interfaces and interaction techniques unveiled. In some ways we need to allow all these new interaction techniques time to settle into the material landscape in order to allow it to propagate into everyday life so that people become familiar with it and over time, develop actual uses that will change and grow in relation to the meaning derived. Only through this use will we be able to actually have meaningful and semantic uses for these technologies.

In the Middle: Content

As was expressed in the preceding subsection, basic technology is needed to facilitate an interactive system, yet without content it is simply an empty shell. In order for meaningfulness to be derived, data or content is needed to be consumed, shared and interacted with by the end user. Content has primarily been within the domain of the designer.

If technology can be considered the material state of interactive systems, than content can be seen as a hybrid or transient state of both the material and immaterial [81]. Although not necessarily tangible when compared to technology, its material existence is there. Music produced from the playing of a compact disc embodies a state of sound, and travels in the material universe to the eardrum to be heard. The embodiment of this sound can be seen under a microscope on the surface of a compact disc, almost like bumps on a vinyl record.

Yet even though content is present, a semantic model is needed for it to be interpreted. Content without context and meaning is just as empty as a blank compact disc. This is realised and has given birth to fields of study such as big data or analytics research. Websites such as Twitter[3], YouTube and Facebook[4] have a cornucopia

[3]Twitter (http://www.twitter.com/)
[4]Facebook (http://www.facebook.com/)

of content, but the organisation and interpretation of this data is just as important as the data itself.

At the Top of the Pyramid: Meaning

What both technology and content aim to ultimately support is the acquiring of meaning by the end user. The immaterial state of meaning is highly dependent on the end user′s interaction with a technology and understanding of its content [98]. In many ways an interactive artwork, product or system is not complete if there is no interactivity and semantic interpretation by the user. An interactive artwork, product or system is only halfway complete if an end user does not meet the combined effort of the technology and content in the middle. Because of this, communication of semantic meaning should be at the very forefront in directing the development of both technology and content. Without this complete cycle, the interactive product or system fails.

8.2.2 Discussion

No interactive product, system or artwork is truly successful unless the above three requirements are fulfilled. Technology is needed at the very base to create a condition for any meaningful interaction with content by the end user to be successful. Content is needed for the end user to have data to interpret and interact with. Finally semantics and meaningful interaction by the end user completes an interaction cycle in order for the end user to be able to derive meaning, and should be the end result of the orchestration of the above described components.

Future explorations on this topic should include a deeper understanding of each level of the pyramid. Discussion on the impact of materiality and immateriality of technology, content and meaning, and how it affects the development of interactivity should also be explored. A thorough analysis of existing case study artworks, designs and technologies using the hierarchy would also reveal a better understanding of how the hierarchy could be extended.

8.3 Regarding the *Measuring* Method of the Proposed Toolkit

Although seemingly incomplete, the potential scope of the *Measuring* method could be an entire body research research onto itself. The philosophical and practical implications of both the *Hierarchy for Interactive Systems Development* as well as the *Interactivity Index* are vast and wide, and are therefore contained in the *Future Works* chapter.

In regards to the *Interactivity Index*, the underpinnings of the possibility for such an index are proposed. Of course without thorough and rigorous testing of such a method, it becomes difficult to justify it, but at the very least this dissertation enables future explorations towards its development.

Likewise the proposed future works in the form of the *Hierarchy for Interactive Systems Development* takes aim at the overall philosophical motivation behind the development of interactivity at the research level. It asks the important questions of *Where should we focus our attention as researchers and developers?* in the blossoming field of experience design, as well as asks *How can we balance our efforts between the development of technology, the design of content as well as the information that said content intends to deliver?*

It is this very implication of *measuring* both the theoretical motivation as well as the practical outcomes of all interactive systems development that makes it so important for future explorations to be facilitated. The culmination of the research presented throughout this dissertation aims to be the starting point of such research.

Chapter 9

Using the Proposed Toolkit

In this dissertation, a collection of tools and methods were proposed in order to help facilitate the activity of experience designing. These tools addressed each step in a common workflow cycle that was derived from analysis of previously existing toolkits, as well confirmed by survey results of researchers and practitioners from primarily the design, and science and technology fields. In regards to the order of workflow that was identified and used for the proposed toolkits presented in this dissertation, the methods in relation to the experience designer′s tasks are represented in Figure 9.1. In the following subsections, each tool will be reiterated from previous chapters in regards to their use.

9.0.1 Description of the Project Genealogical Tool and its Use

The Genealogical Tool is a method to identify thematic trends in a wide body of projects. The success of the tool is dependent on the sample amount of the projects analysed. The tool is meant to be a design research method so insight is the goal of the outcome, not hard data. It is meant to inform the user of the relationships between projects.

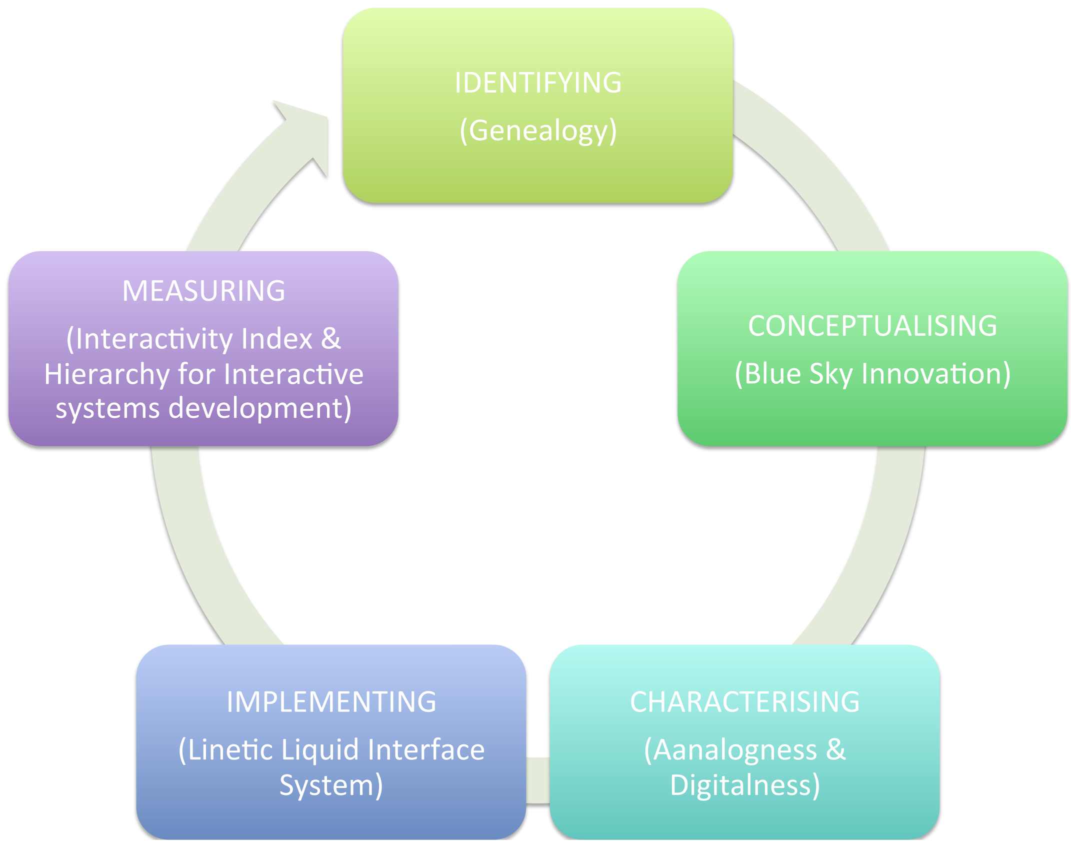

Figure 9.1: The atypical workflow of the experience designer using the IC^{2}MI methods as a unified toolkit.

In order to use the tool, the following steps are required.

Step 1: Identify all projects that are to be analysed (Figure 9.2). These projects should have a previous semantic and/or contextual connection, such as being derived from the same research institute, developed by the same community of researchers, or within the same scope or field of practice.

Step 2: Using a timeline, situate each project in chronological order by either inception, release or initial publication (Figure 9.3). This can be a loose interpretation and exact dates are not required.

Step 3: Attribute characteristics to each project by looking to descriptive keywords (Figure 9.4). In the case of the above projects, keywords were derived from the various published works found for each project. Keywords can be derived from a number of sources. This includes creating a list from published works, abstract descriptions

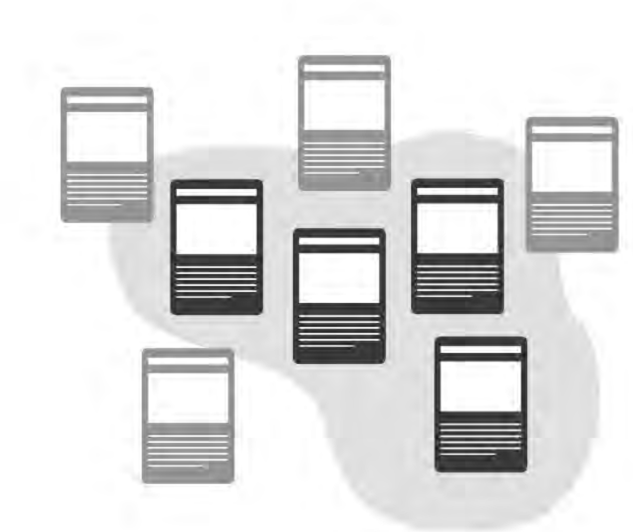

Figure 9.2: Identify and group projects that have semantic and/or contextual connection.

of the projects, etc. Be creative and describe the keywords as you see fit for your particular analysis.

Step 4: Look for overlapping patterns within the keywords that show correlations between various projects and begin to group each project using these keywords against the chronological order of each project (Figure 9.5).

Step 5: Identify the emergent groups of projects according to time and characteristics (Figure9.6). These groups become levels on the genealogical family of projects.

Once all projects have been identified and classified, a genealogy can be uncovered. An example of this can be found in the previous chapter titled *Identifying: A Genealogy of Mixed Reality Lab Projects*.

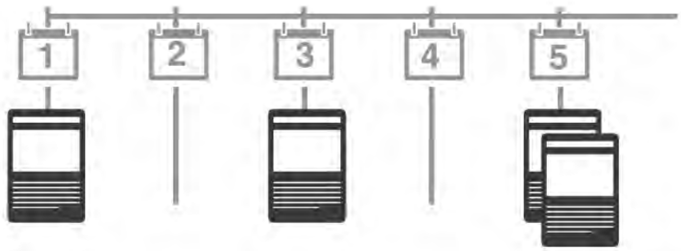

Figure 9.3: Using a timeline, situate each project in chronological order by either inception, release or initial publication.

Figure 9.4: Attribute characteristics to each project using descriptive keywords.

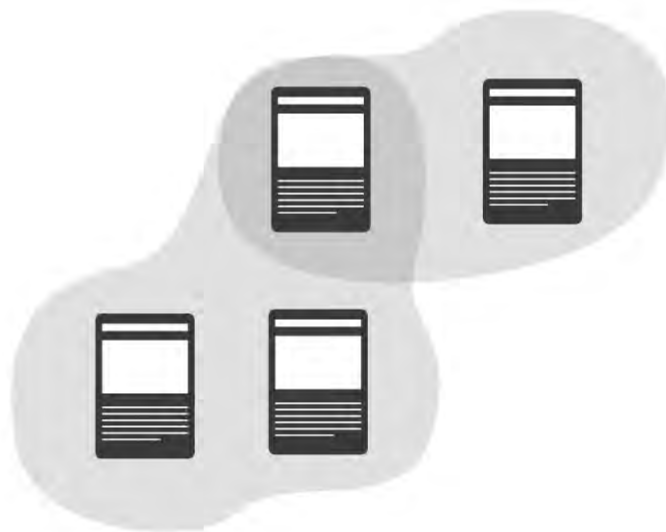

Figure 9.5: Look for overlapping patterns within the keywords that show correlations between various projects and begin to group each project using these keywords against the chronological order of each project.

9.0.2 Description of the Blue Sky Method and its Use

The *Blue Sky Method* is less of a tool but more of an attitude and approach in regards to ideation and concept generation. Whether this has value in a traditional commercial setting is questionable, but the effects of lateral thinking are well documented [29] in regards to developing novel ideas and concepts. Therefore it might be better suited for academic research, where novelty is more important then commercial success, as outlined by one professor from the National University of Singapore, which is discussed in more detail in this dissertation's chapter regarding the survey on the differences between design practice versus design research.

This dissertation does not go as far so as to suggest that one should employ alcohol-induced creativity [129], but a certain lucidness is needed to allow one's thought process to wander. In affect, the *Blue Sky Method* is a mode to express out-of-the-box

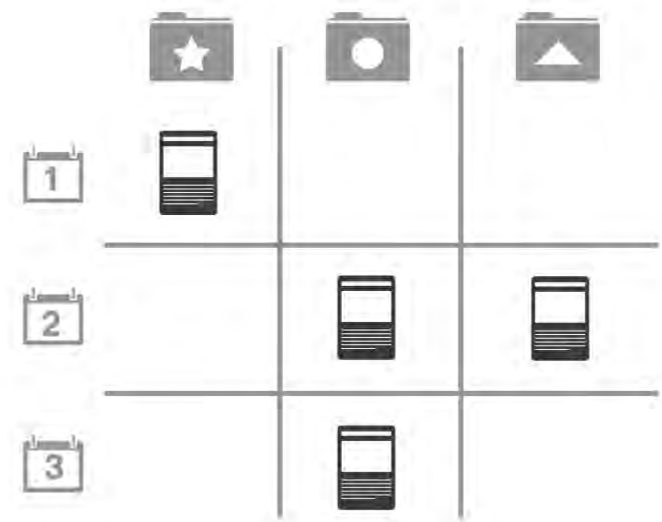

Figure 9.6: Identify the emergent groups of projects according to time and characteristics. These groups become levels on the genealogical family of projects.

thinking, in an attempt to instigate serendipitous results. Serendipity in scientific discovery is defined as an unexpected experience characterised by an anomalous observation and valuable outcome and dependent on an individuals strategic insight [104]. Other fields such as business [38] and education [75] have alternate definitions for serendipity, but for the purpose of this dissertation, and because of the situational conditions of CUTE, Merton′s definition is suitable.

Serendipity may not seem like a variable mode of scientific discover at the onset. Shcaefel and Dumais argue that chance must be synthesised into insight for it to be useful [4]. Yet they also argue that the inventor′s perception may be enhanced to increase the opportunity for serendipity [4]. This could also lead to more creativity and insight generation.

Furthermore the phenomenon of serendipity does not occur without context. McCay-Peet and Toms argue that serendipitous discovery is precipitated by various conditions [102]. Influences from contextual factors such as working environment, collaboration and working conditions factor into serendipitous discovery. The conditions specific to serendipitous discovery at CUTE are outline in a previous chapter. For the *Blue Sky Method* to work appropriately, the understanding of such contextual conditions are needed in order for the method to be enacted.

McCay-Peet hypothesises that serendipity may be facilitated through the design of a system sensitive to external and internal context [101]. Therefore the questions presented in order to direct the *Blue Sky Method* can be classified as external and internal factors.

To outline a specific method in steps in order to use the *Blue Sky Method* are difficult to precisely prescribe. Instead, the understanding of the conditions uniquely attributed to the context of its use must be identified. Questions that should be self-reflectively asked have been adapted from the precipitating conditions outlined in [101], and are based on the model proposed by Cunha [38].

A preliminary set of questions to consider are offered in the following:

What is the readily available knowledge one has at the onset of ideation? What knowledge of existing systems and interaction methodologies does one have before the onset of conceptualisation? What is the immediately available information one has to base a brainstorm on? What are the previous works that inspire one to conceptualise a new work? How do these works influence other works? Understanding the thematic trends in previous systems can act as touchpoints of inspiration, as outlined in a previous chapter regarding the genealogical tool proposed in this dissertation. Knowledge can be considered observable and measurable.

What is the motivation for the work, project or system one chooses to develop? Is the work intended to solve a client′s parameters? Is it to develop a novel scientific contribution? Is it intended as a provocative artwork? Is it a combination of many motivations? Understanding the motivational underpinnings of the concept is useful in providing a direction for the ideation process to follow. Motivation can be considered observable and measurable.

What is the behaviour of the researchers and practitioners when ideating? What is the working culture that the researcher or practitioner works in? What is the working style and method of the individual in regards to their practice? Do they work in a team? How does the team synthesise their skills? Understanding the working habits of the people involved in the ideation and creation process can provide foresight into the factors that will influence the direction of ideation. Behaviour can be considered observable and measurable.

What are the tasks involved in developing the proposed work, project or system? What are the tasks needed to develop the work? How will issues be identified and solved as they arise? How will the completion of one task influence the next? What is the overall process flow that should be employed for the project? Understanding the process of development can influence the direction of the project. Often during the process of development, new insights and directions can occur. Tasks can be considered controllable and manipulatable.

What is the environment in which the ideation process occurs in? Are people ideating in a democratic format? Is the environment setup for free thinking? Are you employing a structured process for ideating? Is this happening at a laboratory? A classroom? A meeting room? A bar? The environment and its situational context can influence the nature of lateral thinking. Cultural and societal norms can also play a role in the development of ideas and concepts. Realising these environmental factors can help steer the direction of ideas as well as the acceptance and rejection of certain concepts. Selection of location as well as understanding the overall environment that the ideation process occurs in can significantly influence the creativity of the ideas generated. The environment can be considered controllable and manipulatable.

Who are the other people involved in the ideating process? What are their skills and interests? What are the skills needed to develop the work? How will multiple skills combine in order to solve any issues that arise? How will the completion of one task influence the next? What are the team members interested in? How will this influence the ideation process and outcome? Are there any personal concerns when working with these people? Depending on interest and skill set, concepts generated in the ideation process could pivot in various ways depending on the perspectives of the people involved. Also working relationships, culture and other personal factors could influence the collaboration process. People can be considered controllable and manipulatable.

In summery, knowledge, motivation and behaviour may be measured and observed, while task, environment and people may be controlled and manipulated. Being conscious of these influencing factors is key to using the *Blue Sky Method*. Using the set of questions above, a formulation of enquiry can be supported as they can be seen as the precipitating conditions to serendipitous knowledge exploration.

9.1 Description of the Analogness-Digitalness Continuum Tool and its Use

The *Analogness-Digitalness Continuum Tool* is a method to situate projects, in regards to the nature and characteristics of the relationship between user and system. It provides a visual means to understand the intensity of a system's *Analogness* or *Digitalness*, depending on a project's disposition towards either end of the scale.

In order to use the tool, the following steps are required.

Step 1: Draw a scale with the headers *Analogness* and *Digitalness* at opposing ends. At the centre of the scale, mark a point. This point denotes absolute *hybridness*. Plot equally measured points between the centre and polar points on both the

Figure 9.7: Prepare an analysis work area by drawing an *Analogness-Digitalness Continuum* (ADC).

Analogness and *Digitalness* bisections. This equates to two points equally spaced out on the *Analogness* bisection, and two points equally spaced out on the *Digitalness* bisection, one point for each characteristic, including the absolute point for *Analogness* and *Digitalness*, as outlined in the section above titled *Characteristics of Systems with Analog-like and/or Digital-Like Interaction*, and not counting the *Hybrid* characteristic, as it will act as the centre, pivot point. This scale will act as the *Analogness Digitalness Continuum*. This is illustrated in Figure 9.7.

Step 2: Identify the project or projects that you would like to measure using the ADC (Figure 9.8). The selection of multiple projects can give one an understanding of the interrelationship between projects.

Step 3: Using the characteristics described in the section above titled *Characteristics of Systems with Analog-like and/or Digital-Like Interaction*, score each project by whether they fulfil each characteristic. Working through the list of characteristics and

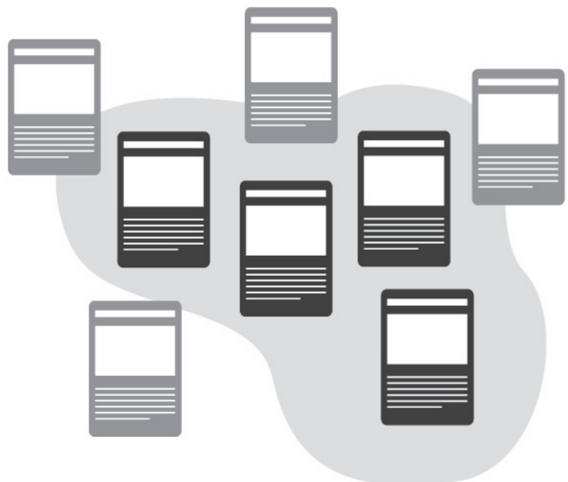

Figure 9.8: Identify the selection of projects to be assessed.

starting from the centre point, move the project plus or minus a step towards either end of the continuum for each characteristic it fulfils. This is shown in Figure 9.9).

Step 4: Once the list of characteristics has been exhausted, and excluding the 7th, *Hybridness* characteristic, the project should fall at its final position on the continuum (Figure 9.10). In most cases every project measured on the ADC should be a hybrid of some sort. The leaning towards *Analogness* or *Digitalness* is what should be noted.

Step 5: Repeat steps 3 and 4 to plot multiple projects on the ADC. This will create a matrix of projects where one can derive the interrelationship of multiple projects.

Step 6: Once the analog-like or digital-like characteristics have been decerned, systems can be re-evaluated depending on the desire to make an interaction more analog-like or digital-like in nature by using the described characteristics as design guidelines.

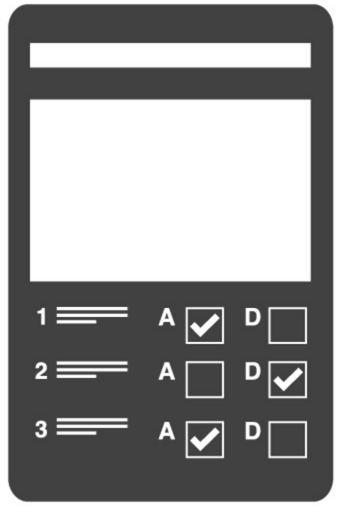

Figure 9.9: Score the selected projects using the Characteristics of Analogness and Digitalness.

9.1.1 Future Tools for Measurement: The Interactivity Index and Hierarchy for Interactive Systems Development

In the future works section, two additional tools are proposed in order to help in the measurement of impact and significance when categorising and developing new interaction methodologies. The first proposed tool is the *Interactivity Index*. This tool suggests the need to attribute a rank to interaction methods that measures the intensity of interaction when using a particular system. Using a quantitative synthesis of measurements based on a combination of metrics gathered through galvanometric physiological response as well as Flow Scale survey, an index number can be derived. This index number would enable researchers to rank all interactions in a standardised list. This is discussed in detail in a previous chapter.

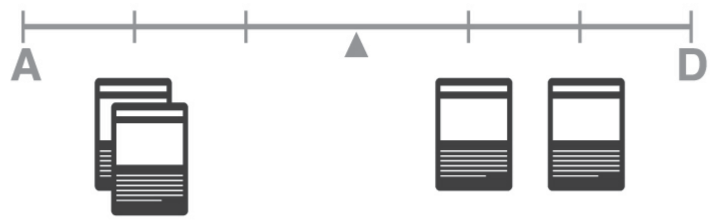

Figure 9.10: Based on whether or not a project fulfills the Characteristics, situate the project on the ADC. Score multiple projects to understand their relationship with one another in accordance with their position on the ADC.

Also discussed in a previous chapter is the Hierarchy for *Interactive Systems Development*. This future work looks to explore the relationship between technology, design and experience, and argues that Meaning should be the main motivation for all technological developments and innovative designs. A detailed discussion is presented in a previous chapter and future exploration of this topic is needed, which is beyond the scope of this dissertation.

Chapter 10

Conclusion

10.1 Conclusion

The culmination of methods presented in this dissertation are intended to act as a complete and holistic approach that addresses each and every phase of the an atypical workflow in which experience designers are engaged with. As a toolkit, the experience designer can apply methods that enable the identifying of interactional themes and relationships between users and interactive systems as an embodied, closed loop integral, conceptualise projects in as an imaginative and innovative way as possible, describe the characteristics that systems and users share as an embodiment, and propose a means to not only measure the engagement of the user with a system, but also attempts to ask the questions of what elements of interactivity development are pertinent, be it from a technical, design or semantic viewpoint. Finally the description of a system that was conceived, designed and implemented by a multidisciplinary team in a research laboratory setting was also described in order to understand how the application of the afore mentioned methods could effect the development cycle.

Throughout this dissertation case studies and experiments were provided to support the proposed methods. For the first method (*Identifying*), a means to construct a genealogy of previous works by looking towards the date of development as well as the existing thematic threads each project posses could be used to organise and deconstruct the relationships that a group of related projects could have with one another. Bodies of work can have little to no initial perceived relationship on the surface, but by looking deeply at possible thematic threads, these relationships become apparent.

The second method (*Conceptualising*) is made possible by using the proposed *Blue Sky Innovation* method. By generating ideas and concepts in a lateral fashion, experience designers can develop as innovative and imaginative solutions as possible. This is done by freeing the ideation process of any type of conceivable constraint, such as feasibility or resource cost. The drawbacks to employing such a method are described in the associated chapter within this dissertation. If used at the optimal time during the development process, the method can facilitate quantum-step innovation, provided that any type of disruptive innovation does not preclude the final outcome of the project. Labs such as the MXR and CUTE employ this method to some measure of success.

The third method (*Characterising*) can be viewed as the *punctum* of this dissertation. Here we provide a method in two parts. The first part describes a universal set of characteristics that can be used to describe any and all relationships between interactive systems and users. This is supported by the analysis of several case studies. The second part of the methods, called the *Analogness-Digitalness Continuum* takes said themes and uses them as a scoring system in order to plot the disposition of *analogness* or *digitalness* an interaction posses. Used together, the experience designer can not only describe existing interactions between user and system, but can also apply such characteristics to future interaction scenarios. Due to the delineation of *analogness* and *digitalness*, we are able to propose a new field of interactive systems development that counterbalances interactive digital media (IDM) called interactive analog media (IAM). Where user and system in IDMs are dichotomistic in embodiment, IAMs propose a means to develop wholly embodied, closed-loop systems that incorporate the user and system into a singular embodiment.

The forth method (*Implementing*) describes a way to develop a user interface based on ferrofluid. Although specific in its description, the Linetic system was conceived and designed using the previous three methods (genealogical study compered to previous MXR/CUTE projects, *Blue Sky* and *Analogness-Digitalness*) and can be generalised towards a way on how to incorporate elements of the proposed toolkit in an actual development cycle. This method is described as a system implementation, and also presents a user study as well as an exploration into the aesthetic implications of interacting with the fluid properties of liquids.

Finally, the fifth method (*Measuring*) is proposed in two parts, which are described as the future works chapter. The potential for further studies are, at the time of writing, significant and are beyond the ability of the author of this dissertation, but are nonetheless addressed in order to enable a starting-point for future research.

The first part of the proposed methodological thrusts in the vein of *Measuring* is the *Interactivity Index*. The *Interactivity Index* is a proposed method to measure the engagement of the user with an interactive system. If we could describe this level of engagement we can then begin to not only analyse the intensity of engagement a user has with an interaction, but also begin to cater bespoke levels of engagement for systems that require special attention without being too engaging (GPS systems in automobiles, for example) or interactions that require complete submersion of the user into the system (cave systems or entertainment gaming systems such as XBox Kinect, which desire a user to be fully engrossed with a task or game).

The second part of the proposed methodological thrusts in the vein of *Measuring* is the *Hierarchy for Interactive Systems Development*. Less a method and more a future research topic, this subsection of the *Future Work* chapter aims to bring light the motivation and purpose of developing interactive systems in the HCI community. It proposes that emphasis be made on the actual purpose and semantics of the development of an interactive system, in relationship to the designing and technological development of said systems.

The role of embodiment is a central theme in this dissertation, as is the validity of current usability testing methods. While the HCI community is currently focused on either the user (user-centric design, design thinking, usability) or the system (ubiquitous computing, tangible user interfaces, etc.), there is little discourse in regards to the singular embodiment of both user and system as one, and how to attribute characteristics and develop tools to address this phenomenon. This dissertation hopes to provide a means for practitioners (with special attention to experience designers) to take concepts of embodiment and incorporate considerations of this phenomenon into the entire process of interactivity development, from identification, to conceptualisation, to characterisation, to implementation, and measurement. It offers study methods and actionable tools throughout the workflow process for developing interactive experiences, and is collectively organised into a toolkit employable by the practicing experience designer for rapid and resource-efficient utilisation.

Appendix A

Survey Form and Results Summary

A.1 Survey Form

Design Researcher / Design Practitioner Survey 10/4/13 5:05 PM

Edit this form

Design Researcher / Design Practitioner Survey

The goal of this survey is to understand the characteristics, similarities and differences between design researchers and design practitioners, if any. Please take the time to answer each question thoroughly and in as much details as possible.

We take your privacy very seriously so the information gathered here will be handled with the utmost care in order to protect your identity. If you no longer wish to participate at any moment during the process, please feel free to close this page and your input will be forgotten - no harm, no foul. Overall it shouldn't take more then 20 minutes to fill out.

We are deeply thankful for any input that you can offer. If you have any questions about this survey, the research, or anything else for that matter, please feel free to email us at <j.koh@nus.edu.sg>.

*Required

Please state your age: *

Tell us how young you are. Don't worry, we wont share!

This is a required question

What is your gender? *

- Male
- Female

What is your level of education? *

Please let us know the highest degree you earned.

- High School Diploma
- College or Polytechnic Diploma
- Bachelor Degree
- Master Degree
- Doctorate Degree
- None of the Above

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Figure A.1: Page one from the Designer Researcher / Design Practitioner Survey presented in this dissertation.

Design Researcher / Design Practitioner Survey 10/4/13 5:05 PM

What is your area of expertise? *

What did you major in during your education? Or, what is your professional area of practice?

- ◯ Design
- ◯ Fine Art
- ◯ Social Science
- ◯ Humanities
- ◯ Business
- ◯ Science & Technology
- ◯ None of the above

Where do you work and what is your current position? *

Point form is cool. Details are helpful. If you are employed or self-employed, please state your industry, company name and professional title. If you are still in school, please state the course of study and institute you are enrolled in.

Please list your previous positions and the organizations you worked for. *

Point form is cool. Details are helpful.

Do you consider yourself a designer? *

A designer is an agent that specifies the structural properties of a design object. In practice, anyone who creates tangible or intangible objects, such as consumer products, processes, laws, games and graphics, is referred to as a designer.

- ◯ Yes
- ◯ No

Do you consider yourself a reseacher? *

A researcher is somebody who performs research, independently as a principal investigator, the search for knowledge or in general any systematic investigation to establish facts. Researchers can work in academic,

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Figure A.2: Page two from the Designer Researcher / Design Practitioner Survey presented in this dissertation.

Design Researcher / Design Practitioner Survey 10/4/13 5:05 PM

industrial, government, or private institutions.

- ◯ Yes
- ◯ No

Do you consider yourself a practitioner? *

A practitioner is a person who regularly does an activity that requires skill or practice.

- ◯ Yes
- ◯ No

Can you consider the work you engage with to be the designing of experiences? *

- ◯ Yes
- ◯ No

Do you consider yourself to be an experience designer? *

- ◯ Yes
- ◯ No

What is your definition of experience design? *

Point form is cool. Details are helpful.

What skills does one need to be an experience designer? *

Point form is cool. Details are helpful.

Do you consider the work you do academic work? *

If you work for a research institute or labratory, where publishing research findings are important, then your work can be cosidered as academic work.

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Figure A.3: Page three from the Designer Researcher / Design Practitioner Survey presented in this dissertation.

Design Researcher / Design Practitioner Survey 10/4/13 5:05 PM

- ◯ Yes
- ◯ No

Do you consider the work you do commercial work? *

If you work for a company or freelance and are engaged with clients, then your work can be considered as commercial work.

- ◯ Yes
- ◯ No

Do you consider conducting research a fundimental part of your practice? *

- ◯ Yes
- ◯ No

Do you think design research is useful in a commercial setting? *

- ◯ Yes
- ◯ No

Do you think design practice is useful in an academic research setting?

- ◯ Yes
- ◯ No

Do you work in a multidiciplinary team?

- ◯ Yes
- ◯ No

What challenges do you face working in multidisciplinary teams?

Point form is cool. Details are helpful. Please be as candid as posible. Don't worry, your boss wont read this!

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Figure A.4: Page four from the Designer Researcher / Design Practitioner Survey presented in this dissertation.

What methods and tools do you use for your work? *

Point form is cool. Details are helpful. Some tools include ethnographic study, tinkering, hacking, interative design, user-centered design, co-design, participatory design, kansei engineering, prototyping, SCRUM, etc.

Which order do you use each tool or method? Please tell us how one method or tool informs the next. *

Point form is cool. Details are helpful. Please use the tools and methods you listed above and discuss the order and reason you use them according to your particular workflow or project.

What do you consider to be the differences between design research in an academic setting versus a commercial setting? *

Point form is cool. Details are helpful. Please describe the differences if any in regards to outcomes, the type and purpose of the data collected, or anything else that comes to mind.

What do you consider to be the differences between design practice in an academic setting versus a commercial setting? *

Point form is cool. Details are helpful. Please describe the differences if any in regards to the outcomes, the type and purpose of the activities practiced, or anything else that comes to mind.

Figure A.5: Page five from the Designer Researcher / Design Practitioner Survey presented in this dissertation.

Please state the importance of research when participating in a project workflow cycle. *

1 being not important, 5 being very important

	1	2	3	4	5	
Not Important	○	○	○	○	○	Very Important

Please state how much time you dedicate to research during an entire project or workflow cycle. *

1 being a short amount of time, 5 being a long amount of time

	1	2	3	4	5	
Short Amount of Time	○	○	○	○	○	Long Amount of Time

Please state the importance of prototyping when participating in a project workflow cycle. *

1 being not important, 5 being very important

	1	2	3	4	5	
Not Important	○	○	○	○	○	Very Important

Please state how much time you dedicate to prototyping during an entire project or workflow cycle. *

1 being a short amount of time, 5 being a long amount of time

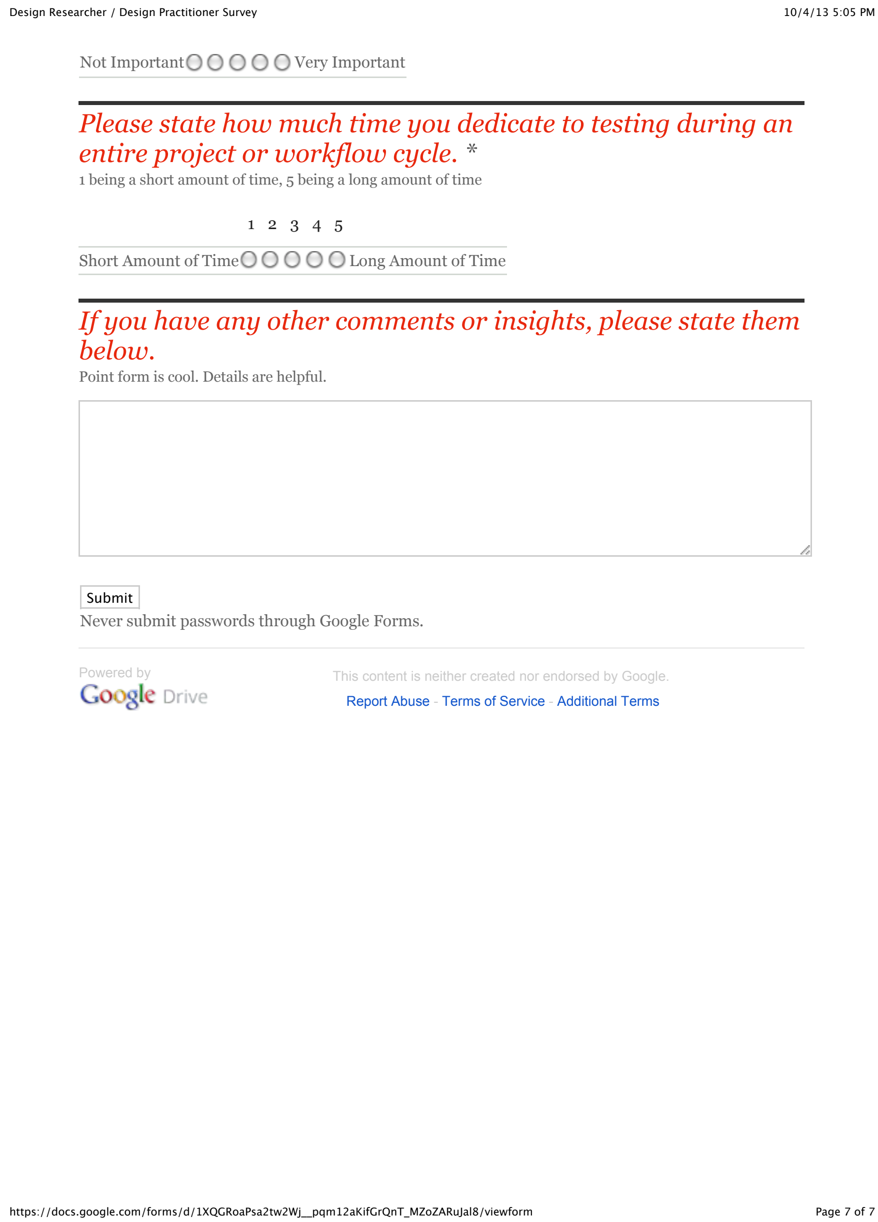
	1	2	3	4	5	
Short Amount of Time	○	○	○	○	○	Long Amount of Time

Please state the importance of testing when participating in a project workflow cycle. *

1 being not important, 5 being very important

	1	2	3	4	5

Figure A.6: Page six from the Designer Researcher / Design Practitioner Survey presented in this dissertation.



Design Researcher / Design Practitioner Survey 10/4/13 5:05 PM

Not Important ○ ○ ○ ○ ○ Very Important

Please state how much time you dedicate to testing during an entire project or workflow cycle. *

1 being a short amount of time, 5 being a long amount of time

	1	2	3	4	5	
Short Amount of Time	○	○	○	○	○	Long Amount of Time

If you have any other comments or insights, please state them below.

Point form is cool. Details are helpful.

Submit

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Figure A.7: Page seven from the Designer Researcher / Design Practitioner Survey presented in this dissertation.

A.2 Results Summary

Design Researcher / Design Practitioner Survey - Google Drive 10/7/13 4:39 PM

jef koh

Edit this form

42 responses

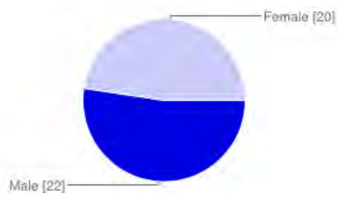
View all responses

Summary

Please state your age:

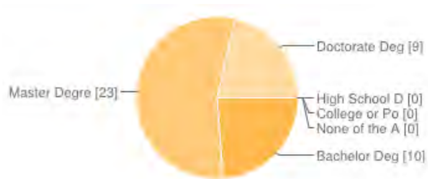
35 36 33 34 39 37 38 22 23 26 27 28 29 30 32 31
Shengdong Zhao 64 47 50

What is your gender?



Male	**22**	52%
Female	**20**	48%

What is your level of education?



High School Diploma	**0**	0%
College or Polytechnic Diploma	**0**	0%
Bachelor Degree	**10**	24%
Master Degree	**23**	55%
Doctorate Degree	**9**	21%
None of the Above	**0**	0%

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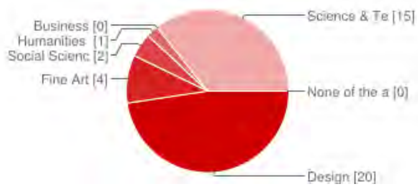
Figure A.8: Page one from the results summary of the Designer Researcher / Design Practitioner Survey presented in this dissertation.

What is your area of expertise?



Design	**20**	48%
Fine Art	**4**	10%
Social Science	**2**	5%
Humanities	**1**	2%
Business	**0**	0%
Science & Technology	**15**	36%
None of the above	**0**	0%

Where do you work and what is your current position?

Research Associate @ CUTE Center master student at the Catholic University of Valencia, Spain. My background are related to product, graphic and digital design. Work Place: Honeywell Technology Solutions Lab, Bangalore, India Posiotion: Lead UX Designer Unemployed Interaction Designer (freelance) currently for Joytingle (a start up) La Presse, a newspaper in Montreal, as a freelance designer/coder/journalist or programmer in the newsroom (the title isn't that clear). (Since late 2012) PhD candidate, doing research on human computer interaction in Singapore PhD Candidate in Cute Center. British Music Experience - Education Manager and Experince Design tutor for Artscom at Central St Martins + I am currently pursuing a PhD at New York University. + My recent research interest is Big Data Analysis and its intuitive visualization. This field requires me to combine the skills of applied mathematics, human computer interaction, big data analytics and information visualization. I teach tech comm (lecturer). University of Michigan. Working on a PhD in educational psychology/educational technology at Michigan State U. I am the founder of Xuna in partnership with Interexpo Co.Ltd work as well as partnership with interior designs I study sustainable design online at the moment with Stanford U. Keio-nus CUTE Center, research assistant for UX. University professor, teaching about HCI and supervising master's and phd research projects in information visualization. T.Ware - interactive media, research and product development - CEO. Sogang Univ. Seoul, Korea / Asst. Prof. Currently unemployed, looking for work as a Digital Designer but having trouble getting a foot in the door in a new city without a network in place. Will probably end up working as a waitress to pay the bills in the short term while I work on my portfolio and do volunteer freelance work for charities. assistant professor Aarhus School of Architecture, Aarhus, Denmark teach interaction design MSc courses at Aarhus

Figure A.9: Page two from the results summary of the Designer Researcher / Design Practitioner Survey presented in this dissertation.

University Head of Projectmanagement for a banking credit bureau Casual lecturer at university Contract programmer/designer Phd student Musician Consultant Geek in residence (yes, there really is such a job title) - Nanyang Polytechnic - Lecturer - Artist in my other life Designer, T.Ware - Chemistry - Senior Designer (product design and workshop facilitation) PhD scholar NUS- CUTE Center Currently self-employed as a graphic designer. Working for clients who need brand identity design for their business. I am an assistant prof. in the computer science department. My focus is HCI. variable technology T.Ware electrical engineer I'm a Software Engineer work on T ware. senior designer at a design consultancy based in Singapore Freelance web usability specialist and technical writer. I design and user-test web sites, write user documentation, and prepare business plans. user experience designer/ asus design center singapore -- // user-driven idea brainstorming // creating scenarios/ story telling, using simple frame to frame illustration or animation video to describe concept // usability evaluation // interface wireframe design, IA (information architecture) // GUI (graphic user interface) design // infographic poster design Composer and sound artist working internationally but based in London Chemistry (2002 - present) Creative Director Responsible for business development, industry engagement, creative strategy, daily business operations. Software Project manager, Online Marketing. Owning an online marketing company. Senior Graphic Designer at M.inc, Singapore Consumer electronic, Asus Global PTE LTD, senior design researcher School of Creative Media, CityU HK I work at University of Adelaide School of Architecture and Built Environment as a Lecturer. Singapore University of Technology and Design Research Assistant/Research Fellow 2013 July- Present National University of Singapore, Researcher im co-director of 72 Hour Urban Action, as well as independent curator on other projects. I am a PhD candidate at Spatial Practices Programme - Central Saint Marins College of Art and Design in London. Also, I work for my supervisor as a communications assistant which is almost like TA.

Please list your previous positions and the organizations you worked for.

IDEO - Interaction Designer (freelance) Self employed in the Netherlands ASK Community Systems - Interaction Designer Lots of internships Designer, Design Incubation Centre, NUS Software Engineer @ Hsenid pvt Ltrd Research Engineer @ Cute in NUS writing center, michigan state. adjunct faculty, English and TESOL departments, Michigan State and Lansing Community College. I have always done this since I was a teenager. I also teach at CSM London Assistant Professor of Business & Technical Communication at West Chester University of PA. Associate Professor of Technical Communication at the University of North Texas. Visiting Instructor of Communication at Western Kentucky University. Kessels Kramer - designer and store manager, London OMA - exhibtition designer, Rotterdam arthesia - creative director IDEO - senior designer, Singapore Chemistry - senior designer, Singapore Software developer (programmer) in 3 companies for 4 years, developing user interfaces, prior to graduate studies. Also worked in research labs at IBM and a hospital during graduate studies. University grad Projectmanager Teamleader Software Engineer - hSenid Software International, Research Engineer - Keio NUS Cute Center Design/Architecture Staff at Atelier Bow-Wow,

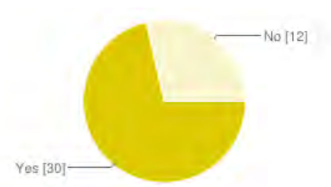
Figure A.10: Page three from the results summary of the Designer Researcher / Design Practitioner Survey presented in this dissertation.

OMA, INABA, Xefirotarch, Michael Sorkin Studio • Graphic Designer at 3nity, Malaysia • Graphic Designer at Fairmont Raffles Hotels International • Self employed for 2 years Universidad Nacional Colombia Museo del Oro Bogota - Architect/Museographer British Museum-Design Assistant Land Design-Design Assistant Metaphor-Design/masterplanner Interexpo Co.-Design and project coordinator Xuna-Founder/Design Federated Dept. Stores, customer service training and tools team Siemens IT Solutions, enterprise business consultant JYU.fi researcher Project Manager - Creative Agency Self Employed - App Development National University of Singapore, PhD Student Undergraduate, Huazhong University of Science and Technology, China Research Engineer @ CUTE Center R&D Hardware Engineer @ Miniatec (Home automation industry) The O2 - Education Officer Freelance - Workshop Facilitator Science Museum - Family and Adult event producer Science Museum - Explainer Researcher - universities and research institutes 13 years - University of Hong Kong, Journalism and Media Studies Centre, Programmer/researcher (2009-2012) - CBC/Radio-Canada, Programmer (2007-2009) - McGill University, Programmer (2004-2006) Research Fellow - NUS 2012 (ongoing) City Artist-in-Residence program| Founder and Curator A long term program for artists residencies in municipal departments in different cities in Israel. 2012 (ongoing) - ArtCube Artists Studios | International Artistic Board ArtCube Artists Studios complex in Talpiot is a center of contemporary culture. It includes subsidized studio spaces for artists, a gallery and an extensive international public program. 2011 Regeneration through Culture in Tel-Aviv | Research Policy paper on the avenues for cultural regeneration in Israel, Tel-Aviv-Jaffa municipality planning department. 2011 Bat-Yam Biennale for Landscape Urbanism Urban Action |Associate Curator A unique civic action model that precedes planned redevelopment in collaboration with the city's planning department. 2010 MoBY, Museum of Bat-Yam for Contemporary Art |Head of Community program A complex of three museums, offering a wide platform for cultural research, theory and criticism. 2009 Art and Architecture Association, London | Curator An independent association advocating joined-up thinking between architects, engineers, planners, artists and academics since 1982. 2007/8 Art in the Open, London | Research Art in the Open is London's advisor for art in the public realm. Part of Open-City, the architecture and advocacy organisation. UI designer/ NUS CUTE center design assistant/ asus design center taipei freelance designer Multimedia Designer at mig33 Pte Ltd Web Designer at Converse Singapore Teaching Assistant at Keio University English Instructor at Gaba Corporation Account Manager at Dimension Data Assistant Manager at a boutique Hi-Fi store Various retail/customer service/admin/hospitality roles Internship at Cute Center, National University of Singapore. sourcing assistant, GE water Sungkyunkwan University, Interaction Science Lab, Research Assistant -Graphic designer -Singapore sports council & 10AM (South East Asian Games 2015 brand identity) Philips Design (Singapore) 1998 - 2002 Design Account Manager / Senior Design Consultant Accounts: Domestic Appliances / Lighting / Mobile / Home A/V systems PhD, CUTE NUS Design consultancy, V12 Design, product designer Design consultancy, Mormedi Design, strategic designer Graduate School of Media Design / Post Doc. researcher Engineering Intern : Lanka Transformers (Energy) Energy Pvt. Ltd (2005 Jan - 2005 Aug) Research Engineer : Mixed Reality Lab/Keio-NUS CUTE Center (2006 Dec -

Figure A.11: Page four from the results summary of the Designer Researcher / Design Practitioner Survey presented in this dissertation.

2009 Aug) PhD Student : Keio-NUS CUTE Center (2009 Aug - 2013 July) Microsoft Research (interned for 2 summer) Post-doc at JST Errato project. Interaction Designer - Dassault Systems, Paris, France Concept Designer - Bell Labs (Alcatel Lucent), Paris, France • Central Saint Martins College of Art and Design - London, Communications Assistant for Patricia Austin at MA Creative Practice for Narrative Environments • Teikyo Foundation UK - UK. Lecturer - Art and Design Japan Women's University - Tokyo, Lecturer - Digital Design Literacy Professor Sunaga Lab at Tama Art University - Tokyo, Mentor for final year BA students + Advisor for international relations Lumsden at Small Back Room - London, Designer - Strategic design / Visual presentation making Discover & Design studio - Tokyo, Designer - spatial, graphic, web and package design Research Intern (On data recovery tools and techniques) in Data Processing of Iran (Old IBM company) Intern for Hardware and PC assembly (private unpopular company) Head of computer affairs in khanehgostar investment company (mainly focus on computer graphic design and technical support) IT researcher in Parsian Bank RA in Cute center PhD scholar in HCI + Analyst, Deloitte Consulting LLP. + Research Assistant, School of Computing, National University of Singapore - OSM Global. Senior designer. Design of camera accessories and mobile phone accessories. Internnships: - Graphics in Vietnam - Furniture in Denmark - Lasalle College of the Arts, part time lecturer - interactive arts - First media design school, part time lecturer - interactive media - NUS Multimodal analysis lab, research assistant - UCLA, teaching assistant

Do you consider yourself a designer?



Yes	**30**	71%
No	**12**	29%

Do you consider yourself a reseacher?

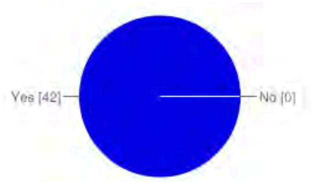
Yes	**30**	71%
No	**12**	29%

Do you consider yourself a practitioner?

Figure A.12: Page five from the results summary of the Designer Researcher / Design Practitioner Survey presented in this dissertation.

Yes	**41**	98%
No	**1**	2%

Can you consider the work you engage with to be the designing of experiences?



Yes	**42**	100%
No	**0**	0%

Do you consider yourself to be an experience designer?

Yes	**28**	67%
No	**14**	33%

What is your definition of experience design?

Applying your life experiences and thoughts on your creation. sounds like someone who builds theme parks or something. but i guess i do this-- I design courses for first year engineering students-- definitely i'm designing an experience. Before I started my current job: Something that wows. Now: A well crafted process/space where everything from the biggest to the smallest has been considered (and designed). It's about preempting and anticipating people's reactions, feelings and responses to their surroundings and ensuring that there is no void or glitch in the process where the user/person is unhappy or annoyed. Seamless, smooth, functional and sometimes wows. It's also about conveying a message (e.g. a brand) at every single touchpoint, again not leaving anything to chance, in order to ensure the bigger message and desired atmosphere is conveyed. define users' expectation translate them it to features or processes select the important ones and arrange them in such a way that won't give ambiguity to users

Figure A.13: Page six from the results summary of the Designer Researcher / Design Practitioner Survey presented in this dissertation.

Embedding interactive operations/processes/etc. into a product/service such that the interactions with the product/service is an intuitive experience to the user. Aspects of design that focus on not only function and use but also the subjective experience and personal meanings thereof for the person engaging with with the designed artefact. Facilitate "conversation" between user and product Purposefully curating the experience that a person/visitor/customer/end user will have at an event or using goods or services, to add value and make the activity more memorable. Considering the environment in which a person will interact with product/service/event as an integral part of the whole. Designing techniques which enhance the way users interact with a system - be it hardware or software. creating a space or environment which allows the occupants to feel and exparience in a particular situation. Experience Design to me is the design of things that you can experience with your body and your senses. The medium is not important, it could be an event, a website, a sound or scent landscape, a kid's birthday cake. Successful experience design is engaging, delighting, surprising, like magic. You want to know how it was done, and you want to do it again! process of interacting with a product. All designers can create experiences because any type of design involves user experience. Experience design is a practice of design with the focus on the human experience and the environment surrounding the human. It's a process of understanding how do people live the experience and how will people live with the experience. Designing for people, for senses, something that cannot remain indifferent to people For me is the practice of designing experiences through design products or objects as well as events and environments, in order to learn, share or teach a subject. It involves telling stories about the product or the user, and even introduce or imagine new environments out of a normal routine or to enrich a normal routine. It can be as well a way to maintain memories or create new narratives in the way we see and interact with the world. I'm not a designer but I think it as user perspective design. designer should think like user. design a system or a process with the system that achieves feelings and experiences on human bringing forth a context that encourages a set of desired experiences designing such that the user might later hold a memory or narrative account that shares in some ways the vision the designer held in shaping an object, event, or process Looking and working with people directly: - Make a test, give it to the people, make clear what is tested and what stage the thing is. - Look preciously at the reactions at the people, take notes - Afterwards ask for feedback, Ask for specific situation where emotional reactions were ... or no at all - Adapt the paper prototype and try again typically it is the design of total, multi-modal experiences. I can say that I do that with other practitioners from other disciplines (eg fine art, film) designing products or services to improve the quality of human experiences or to augment human experiences.. The procedure to find out the wisdom ! Designing products/services through narratives, to enrich people's experience, with multi-disciplinary/co-participatory creative approach. Experience design is the process of designing for the senses – pertaining to factors such as social environment, user-interactivity, etc. experience design (i assume it's about user experience design here) involves all aspects of the end-user's interaction with the product and its services. the product could be simply a website, a laptop, a software interface, or a hotel, a hospital care-taking system, or even a public biking/transportation system. it's not about pull out a

Figure A.14: Page seven from the results summary of the Designer Researcher / Design Practitioner Survey presented in this dissertation.

spec checklist and ask what they want, instead, designers & researchers look into the context, understand who is going to use it, how are they going to use it (how do they usually use it), and what do they do in it. by understanding the persona (who) and scenarios (how and what), an interaction flow will be defined. the difference is that researchers provide insights, while designers solve the problem with designs. there are more that i might not be able to describe it properly, things like seamlessly merging the experience throughout marketing, engineering, industrial design, graphic design, interior design, service and all. Experience design is about delivering a cohesive set of interactions from an end user point of view across a particular 'journey'. The experience should ideally address all facets of the mind and all senses as and when appropriate. It should work to resolve the end users's known needs and challenges and in addition bring an element of new and unexpected experience that will create an enduring memory of that experience. The design to make the experience better. It could be applied in many areas, like the experience on digital devices or the flow of a place we walk in. The intersection of usability and art. Design and science. Designing an interactive experience develop best interaction methodologies for a product or a prototype. - understand users needs - propose solutions to accommodate their needs - deliver the solutions in the best possible way Designing products or services that creates emotional responses. Sometimes I think it is satisfying user needs with a product or services - creating possible interactions based around a core product, concept On my business card I used to call myself a industrial designer 'focusing on user experiences'. I would say the definition of experience designer: Designer who focuses on the interactions between the user(s) of tools, products or services. (and as I am saying this, I realize that this is also my definition of a interaction designer (so not only related to software!) and I would say I am also a experience designer but would not call myself that because not many people know what you mean with it. I think it has something to do with sharing ideas with others, and that sharing is done through communication, and the entire communication process is an experience. Design something for the end user taking into consideration all the touch points and designing it for being a whole and consistent experience that would be memorable Designing user interface or interaction is part of the experience design, so my activities involve a lot of design, although I never formally wear the hat of an experience designer. Design for enhancing the experience of users. Designing user interfaces (or processes or activities involving computers and human users) at the level of overall tasks and high-level activities, keeping in mind the user's environment and goals. This is in contrast to designing lower-level interaction details, such as gestures, menus, interaction techniques, or menuing techniques, which is more what my own work is about. A cross disciplinary, multi-sensorial design approach taking the overall journey of the user into account and mapping it across all relevant touch-points to create one holistic experience. These experiences can have various formats in terms of size, time span or medium eg combining space, communication and UI design to create a exhibition or retail space. experience design focuses on contained and temporary experiences aided by either technology, space or communication.

What skills does one need to be an experience designer?

Figure A.15: Page eight from the results summary of the Designer Researcher / Design Practitioner Survey presented in this dissertation.

Empathic interviewing and observation skills Ability to combine and juggle end customer point of view with back end delivery and constraints Skills in prototyping (physical, virtual, role play) to model and experiment with new modes Comfort with moving from high level strategic view down to small details and back up again Strong skills in traditional design practice and at the same time broad knowledge of other industries (e.g. Healthcare, Retail, F&B, Banking, Technology etc) User centered approach Design research Conceptualization Design methods sensitive on people thinking. Art Creative mind, capable to see the big picture, detail obsessive, user centric and adventurous. Designer should have an out of the box thinking process to cross traditionally accepted boundaries. Further he should have a good sense of people's living style and what they need. Knowledge of future trends Good knowledge in user studies. - keen observations - Research skills - basic prototyping skills Understanding of the way people think and what their expectations will be. The ability to observe behaviour, and to predict the next steps. Knowlege of a diverse range of practices. Project management. Observation and evaluation Self critical One needs to be able to carry out each step of the process from concept to product even if, in practice, you farm many jobs out to more capable specialists. You need to be able to at least conceptualise all aspects of the process as if you make the whole thing. ability to channel the audience (see things through the target audience's eyes) Analysing, data visualisation, typography, researching, as well as empathy and rational thinking. ability to understand, evaluate, and alter the existing and/ot surrounding. - Technical skills to be able to understand the possibilities of the digital storytelling. I think the traditional journalist is very good at telling stories, but his work can be further enhanced if they are able to understand technology or at least not be afraid of its details. - Empathy. Surely, it's important to understand your audience as an experience designer. An understanding of basic design principles (proximity, alignment, contrast, and repetition). The ability to collect qualitative and quantitative data and the ability to visually represent that data. An understanding of effective written and spoken communication. The ability to work with other people and to listen. Have to understand people, how they behave, how they feel Knowledge about state of the art of the technologies, tools that make possible creating this experience As these projects usually implies having many people involved, experience designer must be a good communicator - Very Good Intuition - Be Quiet - Get a Feel how the testers are feeling - Observation - Communicate - Ideate - Rapid Prototyping Background in user interface design, HCI. Also helps to have knowledge of graphic design and experience interviewing users. The designer needs to understand what and who the product/design is for, research/experiment with processes that might result in a positive or negative outcome, and decide on the best solution – with consideration for the end user. + a good understanding of human psychology. + a prototype hacker (doesn't have to be a software/hardware engineer as such). + good designing skills (comfortable with design tools). // empathy, interests and passion to understand what people really need (not just what designer feels like), good communication skill, be objective // need to be able to build persona and scenarios to communicate the story // IA (information architecture) - how everything works in this context // in my opinion it is better that user experience designers can carry some design research skills like contextual inquiry, KJ/card sorting, qualitative user interview, quantitative user

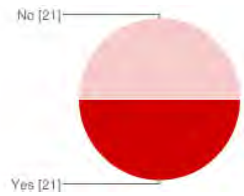
Figure A.16: Page nine from the results summary of the Designer Researcher / Design Practitioner Survey presented in this dissertation.

testing etc. (although big companies do not categorise the job scope like this, they have design researcher to do it. it's somewhat vague.) // lots of companies consider Interaction Design/ UI Designer part of this field. in this case they'll need to know how to use design software (Adobe series) to create an interface, or prototype the function with After Effect/Flash to make it interactive * creative thinking * understanding of people behavior * illustration and product development Imagination Bravery - or the ability to overcome your fear of laying yourself bare for others to judge A thick skin Critical thinking and analysis Research skills A talent for your medium (Graphic design, programming, cooking, knitting, whatever) typically spatial and visual design are crucial, as this discipline is generally considered creativity is the most important for any designer - research skill to understand the domain knowledge where the problem lies - development skill to propose solutions to be delivered I think he just needs to love what he does, ike to jump around through different activities, have the ability to listen to others And the courage to suggest other ways to experience things and events Deep empathy for end users / customers, Knowledge of User centered Design Process, information architecture,Prototyping, Iterative Design, Branding, Storytelling, Marketing, Experiences, Imagination, understanding diversity, empathy to others depends. generally i would say a good knowledge and honest interest in social contexts and situations, a critical observation and interprestation ability, and a good spirit for collaboration and communication on the soft skills side. on the hard skills side a good control of all things digital, not to mention technological. Imagination for the future society, ethnographical approach to understand what target people think. Then have to have a strategy conduct co-participatory design practice. understanding of how time progresses empathy with user and context general skills/craftsmanship capabilities in the desired solution domain realization of expectation of users shape mind about what features are more important than others skills in translation, such as programing or graphic design Depends on what kind of experience? Design research + User experience Graphic Product / Spatial (if it's that kind of experience) Interview, contextual inquiry, survey skills. Prototyping skills User evaluation skills creativity acquire the need of participants teamwork with others evaluate the designed experience T shaped skill - thorough knowledge and expertise in your own field - empathy and good teamworking skills - broad range of knowledge in other areas (eg other design skills, programming, curation, storytelling, healthcare, managment....) Empathy, ability to put yourself in other people's shoes- in order to have the right insights and set up a framework. Relevant design skills to do the actual design. ideas and being able to materialize and visulalize ideas. best: sketch. okay: photoshop or similar not okay: text in products: models critical thinking insightful analyzation imagination immersive sensation Understanding people Understanding interactions (why when how) Designing interactions and products (could be from aesthetic desing to engineering) Prototyping (could be paper prototyping, 3D modelling, electronic design etc) Evaluating (evaluating interactions, interviewing, etc) Empathizing with the user Understanding the market Sketching and visualization techniques Team work ability Imagination and innovation to change your experiences into a form or visual. Skills to use relevant creative tools.

Do you consider the work you do academic work?

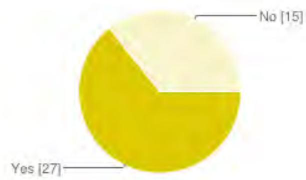
Figure A.17: Page ten from the results summary of the Designer Researcher / Design Practitioner Survey presented in this dissertation.

Design Researcher / Design Practitioner Survey - Google Drive 10/7/13 4:39 PM



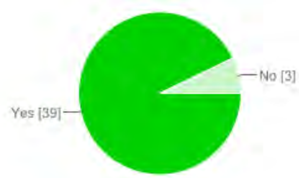
Yes	**21**	50%
No	**21**	50%

Do you consider the work you do commercial work?



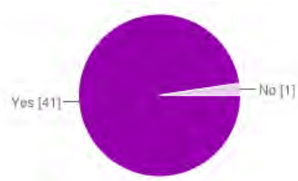
Yes	**27**	64%
No	**15**	36%

Do you consider conducting research a fundimental part of your practice?



Yes	**39**	93%
No	**3**	7%

Do you think design research is useful in a commercial setting?

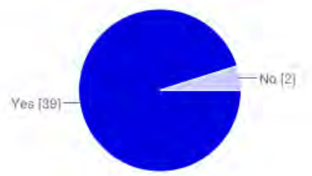


Yes	**41**	98%
No	**1**	2%

Do you think design practice is useful in an academic research setting?

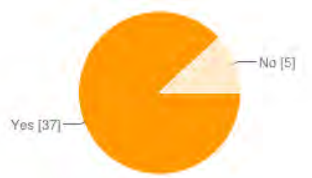
https://docs.google.com/forms/d/1XQGRoaPsa2tw2Wj__pqm12aKifGrQnT_MZoZARuJal8/viewanalytics Page 11 of 25

Figure A.18: Page eleven from the results summary of the Designer Researcher / Design Practitioner Survey presented in this dissertation.



Yes	**39**	95%
No	**2**	5%

Do you work in a multidiciplinary team?



Yes	**37**	88%
No	**5**	12%

What challenges do you face working in multidisciplinary teams?

- Creative - Nothing is always the same - Fun - Exhausting - Personal Challenging but very important I think the most important challenge is explaining our work to the newsroom in order to integrate better with the current processes. Our media used to be paper, and our new flagship product is a daily newspaper on an iPad. The appearance is still very paper-ish, and there is so much more we can do with the digital medium. Time is often our biggest limiting factor, because we work in a daily media. + making sure that everyone is always on the same page. + having a rigid execution process, very little scope for flexibility as any deviation from the defined process affects the work of multiple members. + identifying if the approach others are following is the most optimum for the proposed solution. given the little understanding of other's domain, you always ponder if there is a better way to do their work. Communication is most important. Understand the responsibility. Publishing across disciplines is difficult. Journals are so specialized and reviewers can be very myopic in how they evaluate research. Too many egos. Spending time trying to understand each other, differences in terminology, in goals, in ways of thinking. maintain the balance between the ultimate design and technical feasibility of the implementation Language not in terms of an idiom, but as well of how you express ideas and understand them. Ego :) I am from an engineering background but work with many designers, artists, etc - Main issue is Speaking the same language (ex: visionary ideas vs logical implementations) Communication problem. I think it is not only multidisciplinary team issue. It is from more personal issues. normal team problems. with designers: advanced team problems since design can never be democratic. every one wants/should decide. splitting of tasks is critical. like all teams, working with multipule disciplines is more about how you let a process

Figure A.19: Page twelve from the results summary of the Designer Researcher / Design Practitioner Survey presented in this dissertation.

unfold rather then understanding the finite details of each other's profession. so the main challenges are facilitation of a unified process, which everybody is on board with, and of course, communicating your position with in that. not letting perosnalities get in the way. keep the atmosphere fun. that is key. Other people not being used to working across diciplines, and not being able to understand that someone might have skills outside their official job title, communication. timing. I don't work in a team at the moment // sometimes interpretation can be subjective. i'd always want to do the data coding (interpreting of user feedback) together with the research team so that the outcome more fair - after all it's the designers who have to work with it. // communication between team is critical. even people sit next to each other don't talk much so the insight could get missing on the way. - speaking the same language - filling the gaps - transcending and coordinating between disciplines - creative direction - making sure the overall experience is more than the sum of its parts None - syncing between the teams - finding a common language and understanding Managing different points of view Co-ordinating different outputs into one cohesive whole Dealing with the breadth and complexity of taking on projects that require such a multidisciplinary output It is difficult to find the right resources and right person to solve the problem. The communication between different areas is not always going well. passions and desired audiences are often different Multi-disciplinary within design. Not super challenging, we are mostly on the same page. My old job was all about working closely with sales, production, logistics and paying clients. It was a bigger challenge. However, the company was a manufacturing company driven by a promise (to clients) of strong design so generally within the company there was a lot of understanding and accomodating for the design process (still would not call it research when you have half a day to observe customers ;). More difficult to get clients to buy into it, they just wanted the design asap. Common language - evaluate may mean something different to a sculptor than to an HCI person. scheduling the group meeting keep the members motivated all the time Communication is usually the biggest challenge, designers and developers often speak different languages, so I think it's beneficial to work across the spectrum of both roles as much as you can Pitching ideas, Communication, Finalizing a Design Direction 1) Different goals and measure of success. For example, different disciplines value different venues for publication and have different goals. 2) Shared understanding and communication. Due to different training, the conversation might not be as smooth. Communication - eg. user needs Priorities Mutual understanding Unrealistic expectations Sincerely no challenges. I think a multidisciplinary team enriches the team and helps to create better results. Having different points of view and bringing into the table different experiences of the team members are all for good. Different point of views from different backgrounds make difficult driving the project in a common direction collaboration and understanding between different professionals profiles. People from different background have different logic of thinking, so it is very important to make things easy to understand. Such as info graphic or very simple flow chart, or even just some images with text would help. different priorities different values different languages implement designing ideas to workable prototypes using technology. Need someone who can act like bridge in-between different expertise. I don't know why but in my culture(Japan), people who claim multidisciplinary design approach are sometimes closed off and not so good at communicating each other, nerds. Japanese research

Figure A.20: Page thirteen from the results summary of the Designer Researcher / Design Practitioner Survey presented in this dissertation.

society need to create a balance between "personality" and "ability". Enjoy your own life before bull shitting. different mindset and realization of complexity for example, electrical engineers as me like to give too much attention to details which may not give any experience difference to users, software engineer tend to do things fast but not considering efficiency, and designers may give many advises that may give minor experience advance to users but increase the complexity of implementation a lot. - Communicate the feasibility of ideas to designers - To understand the real need of users. Users lie to you some times

What methods and tools do you use for your work?

Design thinking process ethnographic study, experiment design user-centered design, statistical analyzation field work, focus group -Adobe creative suite? -mind map -pencil & paper eclipse altium ethnographic study (not from me but from my colleagues) prototyping TDD (depending on the project, usually only software based) SCRUM (depending on the project) iterative design (user trials - pass them the product to use for a time) User interviews Expert user interviews Prototyping hacking, physical prototyping, digital fabrication tools, studio format projects, 10 weeks design process with simple basic objectives, sketching both 2d and 3d mapping, interviewing, survey mapping, and systematic project management! i dont know the designing term for that.. Software - Integrated development environments. (Visual studio, Inteli'J Idea) Easy prototyping softwares and tools like Arduino and Prosessing. 3D printer Indicating sequential objectives to achieve to a goal(design outcome). Each stage has different objectives, basic research, understanding stakeholders, idea sketches, idea development, test in Design Fiction, practice, evaluation, etc. It may take iterative cycles if it's necessary. iterative design, contextual inquiry, focus group, controlled experiment, rapid prototyping, brainstorming and research seminar, prototyping, lean practice. Paper, whiteboard, coding up prototypes, usability studies, controlled experiments. - tinkering - hacking - prototyping - research - user centered design - imagination pencil and music paper. Computers and particular softwares Illustrator, Rhinoceros, PIC, Arduino, Android, 3D printing and laser cutting See below Wordpress Web hosting Researching competitors Domain registration User Interface Design User Experience Design Writing Editing Proofreading Style and voice Photography and image editing Criticism and review of other sources Social networking HTML CSS Graphic Design Indesign Illustrator Photoshop Template customisation Plugins Fonts wireframing, brainstorming, segmenting project into various quickly achievable tasks, prototyping, pilot studies, expert feedback, ANOVA, refine. design-oriented research interactive design hacking interview pilot study field study survey paper prototying and user-centered Design Usability evaluation KJ/card sorting Qualitative user interview Scenario/ story telling Idea brainstorming Paper prototyping Flow design Participatory prototyping Grounded theory Action research User studies Screw the literature, science etc. and just design the fucking thing - User-centered design - hacking - Rapid Prototyping User Research, Problem Framing, Concept Ideation, Interaction Design, Prototyping, Usability Testing Interviews, observations, shadowing, journey mapping, opportunity mapping, brainstorming, sketching, prototyping etc... Prototyping use centered design cultural and ethnographic research participatory design Tinkering tinkering

Figure A.21: Page fourteen from the results summary of the Designer Researcher / Design Practitioner Survey presented in this dissertation.

centered design cultural and ethnographic research participatory design Tinkering tinkering, collaboration tools, user centered design prototyping iterative design Scrum Eclipse trello protoyping, scrum, sketching, user-videos, ux tests General research, user-centered design, prototyping, ethnographic study, Interative design, etc. Contextual inquiry. Usability lab testing. Concurrent think-aloud protocol Eye-tracking Web development & design Writing & editing context mapping prototyping user testing user centered design Ethnographic study, field observation, in depth interviews with users, house visiting, mapping, framing, opportunity map, customer journey, secondary research, aloud protocol, role playing, prototyping, brainstorming. a human centered design approach -design research -- interviews, observation, shadowing, immersion, desk research, - creative workshops with the clients --persona profiles, journey mapping, mood boards, brainstorms - design work (usual software, sketching, - prototyping Prototyping Survey Participatory design tinkering Case studies Animation Web Design Marketing Collateral Design ethnographic interviews observation shadowing immersion prototyping (physical, digital and role play based) sketching and illustration creative workshop facilitation 2D and 3D CAD model making report writing keynote talks Information and typography design for print work Academic research surveys Iterative design Participatory design Prototyping Tinkering Hardware Hacking lots of studies communication with client understanding of client needs improving clients needs phisical and digital models My work doesn't involve design techniques so much. My research is done "intuitively". Say, I have to do an interactive graphic on hockey, I would go to hockey sites to see how a story is currently being communicated and see how I could do it better graphically.

Which order do you use each tool or method? Please tell us how one method or tool informs the next.

ethnographic studies and prototyping come first. Once is defined the project with a clear plan then SCRUM and TDD may be applied STRATEGY keynote talks Articles Interviews Papers RESEARCH ethnographic interviews observation shadowing immersion prototyping (physical, digital and role play based) sketching and illustration IDEATION sketching and illustration creative workshop facilitation 2D and 3D CAD model making DELIVERY report writing technical drawings, CAD data or graphics for manufacturing / printing / coding - imagination (this is where it all starts, it forms the basis of everything to come) - research (to refine) - tinkering, hacking - prototyping - user centered design (if needed) Research on the target user and his context ,ideation, Sketches, Tinkering, prototyping, evaluation (FGI, video obsrvation), iteration process not fixed Prototyping is the beginning but I jump between all of them Grounded theory's has many parallels with an artist's ongoing dialog with materials and tools. Both involve such questions as, "what is this? What is happening? What does this mean? What higher level categories might this belong to? How do these categories interact and fit together? Both involve iteratively moving between levels of abstraction. sketching 2d and 3d allows communication among the team hacking and physical computing tools to mock it up with some functionality, deadlines and goals that are short and acheivable to drive progress -mind map: to stretch the ideas -pencil & paper: to sketch out the ideas -Adobe creative suite: final artworks... Collect information/research, consider requirements/needs, classify and arrange information for

Figure A.22: Page fifteen from the results summary of the Designer Researcher / Design Practitioner Survey presented in this dissertation.

consistency, explore design options, and find the simplest way to communicate the information to the audience using typography, colours, info segmentation and layout.   Idea generation (could be from any thing : improving existing, notice differences, brainstorming, etc) Research for existing technologies (try to identify technologies/processes related to the idea, this could lead into identifying ways to implement, and also identify which features could be added or removed, or simply stop if a closely similar product/tech exists) Prototype (make an initial version of the product that is presentable to a user) Present to users for evaluations (get the users' feedback, ideas, potential new application areas, evaluate for usability or other metrics) Based on feedback tinker/hack or create new prototype Iterate this process   User-centered design guides the hacking and the prototyping.   // Idea brainstorming (always different ways) > KJ/card sorting (for sorting out ideas from the brainstorming) > Scenario/ story telling // Usability evaluation (if there is a product soon out in the market, we need to make sure that it works well for the users) > KJ/card sorting (sorting out insights from the evaluation) // Qualitative user interview (seldom, only if it's needed in the project) > KJ/card sorting (for sorting out insights from the interview) > Flow design (interface interaction) > Paper prototyping (to do a quick test and see how it works)   Survey (previous works): to find the gaps and problems Participatory design: To empathize with user and figure out the form factors tikering and iterative prototyping : To facilitate brainstorming and then again go back to design   1) context mapping -> getting to know the stakeholders, users and context. This involves design research with for example ethnographic research. This serves for inspiration and information 2) prototyping --> Early in the design process prototype the rough ideas to test with your team and the intented users in the intended context. 3) user testing --> Is said at point 2 User centered design is the entire process.   1. Identify a phenomenon. 2. Research the academic literature. 3. Formulate a research question. 4. Identify appropriate publication venues. 5. Design the study. 6. Submit the study to the IRB. 7. Wait. 8. Recruit participants. 9. Run the study. 10. Analyze the findings. 11. Write the journal article. 12. Edit the article. 13. Submit the article. 14. Wait for reviews. 15. Revise and resubmit.   research seminars, contextual inquiry, brainstorming, rapid prototyping, interactive design, user evaluation   1. ethnographic study, field work 2. focus group 3. experiment design 4. statistical analyzation 5. user-centered design   I've already mentioned on the above.   User understanding > identifying "voids" in their process > ideas around how voids can be eliminated and turned into positives > addressing them in relation to the overall process/space/product > further develop relevant ideas   User Research, Problem Framing, Concept Ideation, Interaction Design, Prototyping, Usability Testing   1 - General research. 2 - Ethnographic study 3 - User-centered design 4 - Interative design. 5 - Prototyping.   prototyping user centered design iterative design users have to be shown a prototype of the solution in order to imagine how it can help them. Further understanding of usability problems are then necessary. finally we need to reiterate to find the best solution that may also solve some by problems   Research - reading books and using the internet Audience segmentation - observation of who the participants will be and their social demographic - this leads to further research. Mind mapping and discussion with collegues or drafting in other experts in specific fields. Testing in real life situations, Evaluation - surveys, observation, conversations Continuous observation throughout the run.   Phase 1 - Research

Figure A.23: Page sixteen from the results summary of the Designer Researcher / Design Practitioner Survey presented in this dissertation.

into technologies, competitors and design requirements, discussion with client on their purpose and previous experiences Phase 2 - Gathering tech tools and registrations (domains, hosting, etc.) Phase 3 - Paper design, wireframes, consult with client (navigation, content) Phase 4 - Build and customise (wordpress, html, css, templates, fonts, colours) Phase 5 - In-house testing Phase 6 - Customer feedback, redesign or signoff Phase 7 - Go live Phase 8 - Handover or continue management Phase 9 - Continuing content and community engagement i cant really answer this question.. Prototype on paper or whiteboard or as static images, then as code, then evaluate in some way with usability study and/or controlled experiment. Goal is to get paper published at top conference and get lots of citations! blah IDEs : Develop software programmes quickly and efficient way. For UI designs Arduino and Processing : Create quick prototypes for concepts. 3D Printer : Prototyping + the project starts with initial wireframing, followed by multiple brainstorming sessions to improve the proposed wireframe and identify the features to be included. + then we segment the project into multiple tasks, focusing on one or more task at a time. + then we do prototyping, followed by a pilot study. + then we seek expert feedback and/or large scale user study and gather qualitative data. + we perform ANOVA then to gather quantitative data. + if there is a requirement, we start refining the system and go back to one of the previous steps accordingly. Depends on the projects and the methodologies that have been used. For example: Observation and in depth interviewed brings insights into the framework, analysing this information leads to an opportunity map. This opportunity map will be the base for a strategy or for the development of a new project. After receiving design requests, studies on relevant cases and concept building will follow. One of the designing method will be selected according to which form/visual is to be made. altium to design pcb eclipse to program 1.cultural and ethnographic research 2.participatory design,Tinkering, use centered design 3.Prototyping pre: text, wireframe, visualization project: model, code based on scrum testing: functional test ux testing: from time to time user-centered Design: - Paperprototyping as early as possible design-oriented research to guide the research interview to gather the overall opinion from users user study to get deeper understanding of user experience I'm not so sure! * Illustrator: illustrate and improve the initial idea * Rhinoceros: 3D modeling and product design * PIC, Arduino, Android, 3D printing and laser cutting: prototyping and implementation to study further Discover - research Define - looking for patterns and insights - coming up with opportunities to improve and innovate Develop - coming up with design direction, concept design and final designs in an iterative process through repeat prototyping and testing Deliver - final design and production this tool are work independently Research/ Interview Prototype Test / Get feedback Repeat communication with client understanding of client needs improving clients needs lots of studies phisical and digital models communication with client understanding of client needs improving clients needs lots of studies phisical and digital models repeat process until finish

What do you consider to be the differences between design research in an academic setting versus a commercial setting?

I don't know; I've never conducted research outside of an academic setting. More time! In a

Figure A.24: Page seventeen from the results summary of the Designer Researcher / Design Practitioner Survey presented in this dissertation.

commercial setting it is difficult to convey the client that this research is useful as the outcome is not know and rather vague at the beginning. The client sometimes believes in his own assumptions and thinks he knows his users. In a academic setting I think this is less of an issue and the collected data can be more elaborate as there is no time/money pressure. Academic setting I think is more open to experiment with new areas than commercial setting which is more focus in branding. Also most of time commercial settings are defined as event or campaign base rather than long term research or study. NA The two should be connected. It should not be so different. Both should feed backinto one another. Research in commercial settings are mostly to see what's been done, what suits the clients' requirement, and what's the competitors' strategy etc. in my previous company, as I assumed, academic will go further than that, to collect data from more aspect than just how to make profit. I'm not sure that there is one, however I have come across a difference between the ways research is used in a commercial vs audience focused setting. A large music venue that I happen to know has a data management system which they use to handle the emails they recieve to their customer services team. This system is set up to enable them to process the emails they recieve more quickly, and to monitor the flow of information so they can see which staff member has dealt with the most complaints the quickest. It is not however capable on reporting on the type of contact they get (complaints, feedback, issues, lost property, etc) or the general levels of customer satisfaction - a conversation is flagged as resolved when the customer stops replying. The data generated is used to design a better system from the point of view of the company - not the customer. They use the data to design a 'better' system for answering emails, not a better system for deailing with - and ultimately eliminting - customer issues. The biggest differences I think is for a commercialized product the most important issue is marketing, and possibility to make profit. Designers needs to consider it most, and some times it limits the creativity Academic: With more time, design research is more extensive, with a wider spectrum of studies and more possibilities of connecting disciplines during the design processes, with no direct application to everyday design practice. Commercial: Less detailed study on the subject/product, focus is more on the end user requirements. design research has more freedom. Could test different interaction methods and protypes. In the othr hand commercial setting we have to stick to the limited budget and needed to make sure new inventions should meet company expectations. In an academic setting, design research focuses on gathering data and finding patterns in it where as in a commercial setting it focuses more on gathering insights through observations. Design research in an academic setting is either based on: - Researching a high level or non-commercial but necessary topic - Researching the process of design and design thinking tools Commercial research is about addressing specific needs or industry domains of the client, with a focus generally on revenue generation as a primary concern. academic setting focuses more on the contribution to the research domain, like the knowledge, design principle, guidelines etc. commercial setting is more driven by the market trend, user needs, and profit. the aims and objectives. Straight academic research is typically more 'blue sky' In one, the goal is to make something for a purpose or context In the other, the purpose is to build knowledge Both are trying to predict enough to get to a satisfactory outcome. Speed.. time constraints in a commercial setting and a fixed production date means

Figure A.25: Page eighteen from the results summary of the Designer Researcher / Design Practitioner Survey presented in this dissertation.

less time to explore, research, the need for a very defined research focus academic outcomes are for dissemination and platforms of communication, commercial design research is focused on developing a brand or business academic goal seems like is replicability, more concerned with research validity but not whether maps onto real world/ opposite for commercial? my opinion is that research in a commercial setting is very important in how you deliver the insights, and how designers (of all field) can make use of it. after all it's all about implementation of ideas, so if the scenario is not making sense or is not reasonable/feasible, less the value of research outcome can bring about. bridging is the key. while in academic setting, it's all about exploring and making it profound. scenarios created might not be reasonable or realistic, sometimes very blue-sky, which are fine, because the main thing is about the ideas. (well 6 senses guy did it very innovative but still realistic, just in that case, visibility and normal people's acceptance is higher) yes. you get more done in commerical work, since only the result counts. Academic - research for things to come in the next 5 - 10 years Commercial - research for possible integration in the near future (1 - 5 years) I think in academia, you would have more time to do your research. I don't have much experience working as a designer in academia, but when I improvised designer, I would often have access to specialists of the topic I wanted to communicate for. Say, for tools on studying social media, I have easy access to colleagues, students of our school, who were my day to day would-be users. + in commercial setting, the end result is more refined, less buggy and easily replicable. + in academic setting, the novelty of a design is given priority. however, in commercial setting, the feasibility of a design (and if it can be pushed to market) and ease to use of the final outcome are focused upon. Academic: less of a need to be practical, can be longer term / more forward looking and less constrained. 1. in an academic setting design research could be more diverse and flexible 2. in a commercial setting usually there is a design flow within the company. From the user research to design, most of the steps have to follow the convention. i have no idea In my case I usually use the same order of investigation for academic setting and commercial setting. as I havent worked as design researcher in an academic setting this is hard to say, but my guess would be: academic: - less limitation through feasibility and budget - more regulation and rules to follow academic standards - less flexibility in changing the research plan and coming up with new tools and processes - longer time frame - It is easier to be influenced in your result if you have a clear goal in mind, whether academic or commercial. - Tighter timelines in commercial. - Commercial research has to result in conclusion, academic research may be more exploratory (?) Not really sure, but I think a commercial research would be more focus on products or services that are going to be release in a near future, while academic research can approach a topic that is more advance and can benefit of having more time which translates in a more detail and scientific research. Design research in an academic setting will start from a question or idea set by an individual, while commercial settings normally come from solving problems or requests from client and stakeholders. Academic settings look for novelty while commercial setting looks for commercial success. That's the main difference. The academic research needs some setting for more something new ideas and clear contributions to academia, rather than commercial hits and success in commercial settings. Commercial setting it is very focus and time is very limit. I feel like research is not as valued in

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Design Researcher / Design Practitioner Survey - Google Drive 10/7/13 4:39 PM

commercial settings. It's sometimes not recognised as a legitimate work function. In academia of course research is supported, but getting the tools/funding/team to do the job can take up more of your time than the research itself. My understanding is, both are important to develop and disseminate design ideas. But maybe academic setting is more connected to political aspect of our society rather than commercialism. - time line is much shorter for commercial setting - need to be much more focused on deliverying value that can be monetized. I would say research in academic settings has more chance for more open/radical ideas. I feel this is due to the less strict requirements for KPIs such as academic papers, etc and the ability to secure more grants for more open ended grants. I.e. failure in a design research product could be another results where in a commercial setting, it could be a huge set back for the commercial entitity. This does not mean that commercial entities do not come up with new radical ideas. I would say that these entities are focused more on designing for products that are generally required to be successful. This may need these entities to focus on proper guidelines and methodologies where as the academic community has more flexibility in this regard to "explore" potential areas. in commercial the focus is on financial benefit in research might be unrealistic and high cost with publication potential * in an academic setting we have more freedom and time to design and study its acceptance than in a commercial setting. * which has both pros and cons the academic setting allows for radical expreimentation while the commercial one might not, even though sometimes it does. there is less money and more politics in academy then in commercial practice. commercial settings can be more canonical, less exposed to alternative thinking then academic ones. The time framework are different, in a commercial setting the outcomes are expected sooner, In a commercial setting the "mistakes" or unexpected outcomes are less welcomed even when they bring more interesting data The commercial is looking sometimes for specific outcomes, while the academic can be more experimental

What do you consider to be the differences between design practice in an academic setting versus a commercial setting?

not sure Academic - sometimes they make things that have social, political implications and/or things that might not be immediately useful but brings about questions about the world and ourselves. Commercial - very directed outcomes. design practice in commercial setting has more aspects to consider. take industrial design as an example, things like colour and materials choose, competitors, cost related issue are there to give you headache, also there are things to do with marketing, customer acceptance etc. in an academic setting, excuse me if i don't know much, design practice is more like a prototype - as long as it works. of course it still can be great, but somehow it's not going to be sold in the shop, there are relative fewer issues to consider. i don't doubt that design is not necessary in academic setting, especially when it comes to testing or publish/promote the ideas, good design solution is likely to make the idea more convincing. I think time is a big factor between working in academia versus commercial, so far. Another is probably your audience -- in academia, you communicate to other academics or specialists of the given field. In the commercial setting of the daily iPad-based newspaper, you are very general public (even more so than versus a news website, where there is somewhat more fluidity in terms

https://docs.google.com/forms/d/1XQGRoaPsa2tw2Wj__pqm12aKifGrQnT_MZoZARuJal8/viewanalytics Page 20 of 25

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public (even more so than versus a news website, where there is somewhat more fluidity in terms of traffic). Academic settings = prototypes, time spent on refinement Commercial settings = products, to sell = time spent on supply sourcing, streamlining for manufacturing, product testing, product certification, customs/export issue, warranties, marketing, invoices, etc etc. business settings are much more constrained Yes as there are usually tight time allowance in commercial projects, and the idea/funding/creativeness might be quite limited due the clients. Whereas in academic we are allowed a bit more of freedom to do what we want, therefore in the academic we can go deeper in details. I think in a academic setting design is used to test assumptions and the final design can be a tool to get to know something, the tool cannot be used to be sold or used in real situations for example. I think in a commercial setting, the product should be finished and to be monetized. academic settings has more flexibility for failure therefore has potential for more "explorations" Commercial settings (I feel) are generally customer oriented and the design practice could be requirement driven. Commercial settings may adhere to standard practices and processes where as academic settings has the flexibility to deviate from this. dunno design practice in an academic is setting more like Activism for ethical purpose, making an effort to enhance society. A commercial setting has the aim to activate economics to enrich the target society. NA + in academic setting, we have a couple of standard design practices which are used as a baseline to create new techniques. it's quite flexible in nature and we are free to argue the advantage of one practice over another. + in commercial setting, we have a more defined process where we follow a set of practices which are already proven to work and give required results. The commercial is more incremental and practical Sorry I have no Idea. I think the main purpose is different. The academic research case, sometime, the iterative process is meaningful and valuable in design practice but it is important to produce acceptable and good results from iterative design practice in commercial, more explorative and ready to fail Commercial setting should be something reliable and strong since you are representing somehow your company.Academic settings are more open to explore and therefore it is usually reflected on the deployment stage. There can be limitations as budgets and client preferences The use of innovation (materials, ideas, ways of doing) that can be a main subject in academics is not in a commercial setting The deadlines and use of the time is different, the time framework for research and fabrication are different Here I don't see so much difference. I can see that the design practices in an academic settings could be the result from a previous research or from a further exploration in collaboration with students. This could be very nice for the students that can see first hand how to put in practice their studies. There's very little difference if the research question is relevant. Controlling for variables is probably the biggest difference. Similar to the question above, it can be independent of a client brief and a revenue generating imperative. In addition it can explore the process and tools of design rather than their application into another context. Academic: Design practice had endless possibilities. It varies and is more flexible, depending on the research and methodology used for design processes. Commercial: Design practice solely depends on what the clients need, with external considerations such as budget, guidelines, time etc. - not sure 1. design practice, humm, in an academic setting, could be more sensual and less constrained by commercial environment. It is more useful for solving new problem in academic setting rather than in a commercial setting. 2. It would be more efficient for

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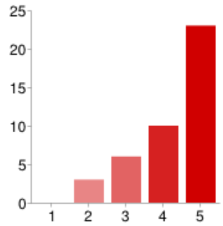
design practice in a commercial setting than academic setting. yes. you get more done in commerical work, since only the result counts. Academic: design ideas can be based more on designer intuition, theory, and novelty and less on needs of real users. academic setting is more about prove design principle and evaluation using prototyping commercial setting would focus more on the preference from consumer's point of view, like appearance, price, popularity, etc. Same as above, I think. Design practice in a commercial setting is far more focused on short term outcomes, and is project specific. I feel like I can be more agile and effective, since the client has a requirement to be met so there is a definite end point and so a definite measure of success. In academia in the case of working for a project or client, I find design practice to be sometimes... cliquey and egotistical. There is often a right/wrong way, and that differs depending on who you ask. Requirements are often unclear or change without notice. I feel like because clients often don't have as much of a personal monetary investment, that can get bogged down in details and process rather than the end result. The other side of design practice in academia is working for yourself. It's great - heaps of freedom, but there's no money in it! Same as above It all depends on what are you creating and to what level? Design practice could be the same in both settings. Academicians build (only?)prototypes to prove their findings/ inventions where as in a commercial setting, products are built which can be used in daily life. There shouldn't be. as I havent worked as design researcher in an academic setting this is hard to say, but my guess would be: academic: - less limitations through budget and client needs and demands - longer time frame - less exposure academic setting: the people still following order and formally discipline. commercial setting: people usually work in a more disorderly way and tend to forget some steps in the investigation. The outcome or aim is different. Whle both would be to improve the products/services/experiences on offer, an academic setting would be focused on enriching the experience for the user, while the commercial setting's main aim woudl be to create more value for the business itself. Commercial setting it is very focus and time is very limit. An academic practice will be more experimental and flexible in the tools and method of design they use while a commercial setting will limit the tools and method to manipulate the form, visuals, etc. I don't have much experience with academic research, but in general I imagine that it pushes the boundaries more than commercial research does. It is allowed (and expected) to be more exploratory. More research for the sake of research. (when used by designers in their academic research) As the design process is a slightly different approach to problems, I can imagine that it may give a wider range to the outcomes of research when added to the research tools of someone outside the design field. (when used by non-designers to problems not associated with design) See above Well in commercial Setting you often have a kind of time preassure ... if this is good or bad, I cant tell ... "The Idea" sometimes needs some time constraints. the academic setting allows for radical expreimentation while the commercial one might not, even though sometimes it does. there is less money and more politics in academy then in commercial practice. commercial settings can be more canonical, less exposed to alternative thinking then academic ones.

Please state the importance of research when participating in a project

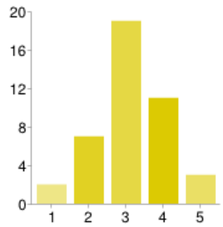
Figure A.29: Page twenty-two from the results summary of the Designer Researcher / Design Practitioner Survey presented in this dissertation.

Please state the importance of research when participating in a project workflow cycle.



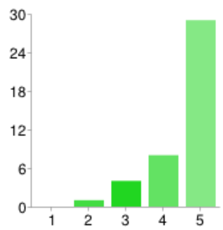
1	**0**	0%
2	**3**	7%
3	**6**	14%
4	**10**	24%
5	**23**	55%

Please state how much time you dedicate to research during an entire project or workflow cycle.



1	**2**	5%
2	**7**	17%
3	**19**	45%
4	**11**	26%
5	**3**	7%

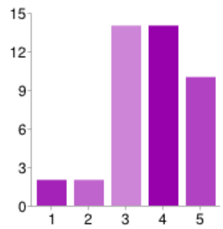
Please state the importance of prototyping when participating in a project workflow cycle.



1	**0**	0%
2	**1**	2%
3	**4**	10%
4	**8**	19%
5	**29**	69%

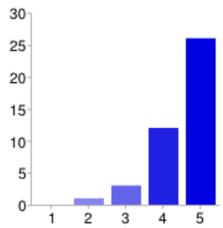
Please state how much time you dedicate to prototyping during an entire project or workflow cycle.

Figure A.30: Page twenty-three from the results summary of the Designer Researcher / Design Practitioner Survey presented in this dissertation.



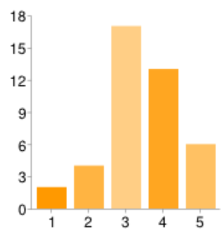
1	**2**	5%
2	**2**	5%
3	**14**	33%
4	**14**	33%
5	**10**	24%

Please state the importance of testing when participating in a project workflow cycle.



1	**0**	0%
2	**1**	2%
3	**3**	7%
4	**12**	29%
5	**26**	62%

Please state how much time you dedicate to testing during an entire project or workflow cycle.



1	**2**	5%
2	**4**	10%
3	**17**	40%
4	**13**	31%
5	**6**	14%

If you have any other comments or insights, please state them below.

This questionnaire is very academic !! As a person involved in architecture practice, everything we do have a research componet to it. And with every building we built, we are pursuing certain agendas, which is ahnd in hand with research, in my opinion. Congrat! Dr. Jef :D All the Best on your thesis and take care man :D feel free to contact me via guntram.bechtold@starsmedia.com for discussion, interview or statement. it's a great study,

Figure A.31: Page twenty-four from the results summary of the Designer Researcher / Design Practitioner Survey presented in this dissertation.

though it says 20 minutes and i ended up spending almost 2 hours... sorting out thoughts is so slow for me. Good luck! I am also struggling :S Interested in knowing results...:) It is difficult to describe my 'fine art' working practice in design terms, though of course there are design elements in it and much of the two areas of making, particularly in developmental methods, is common ground. I would say it is typically less overtly methodical than design practice. Hi Jef, my answers are quite generic (and not very academic) but hope this helps. Ping The last three sets of questions are someone interrelated and form part of the same overall design process of researching > ideation > prototyping > testing > iteration > final delivery. The time and scope is dependant on each project. The key is to avoid skipping any one of those steps vs the actual length of time. It's a nice attempt to try to figure out the difference between academic designers and commercial designers, but I feel that more open ended questions regarding a real design case study might provide more interesting insights. Good luck with your research :). Cool study! Could I see the result of this survey? Is it going to be opened to public? ryo I think it's really tough to integrate real good design research in everyday work in a daily newspaper, because of time. I think you gotta approximate, say publishing stuff and then evaluating its success and bring improvements in the next project you're going to publish.

Number of daily responses

Figure A.32: Page twenty-five from the results summary of the Designer Researcher / Design Practitioner Survey presented in this dissertation.

Appendix B

Publications, Awards and Media Appearances

Appendix B lists the publications, patents, awards and media appearances that were both related directly to this dissertation, or occurred during the author′s PhD candidature. These are listed in the *Related Publications, Patents, Awards and Media Appearances* and *Other Publications* subsections, respectively. Each item is ranked chronologically.

B.1 Related Publications, Patents, Awards and Media Appearances

B.1.1 Journals

- Koh, J. T. K. V., Zhu, K., Karunanayaka, K., Polydorou, D., Peiris, R. L., & Nakatsu, R. (2013, January). Characterizing the Analog-like and Digital-like Attributes of Interactive Systems. Communication of Design Quarterly, 1(2), 836. doi:10.1145/2448926.2448928

- Koh, J. T. K. V., Karunanayaka, K., Sepulveda, J., Tharakan, M. J., Krishnan, M., & Cheok, A. D. (2011). Liquid Interface: A Malleable , Transient, Direct-Touch Interface. Computers in Entertainment (CIE), 9(2), 18. doi:10.1145/1998376.1998378

B.1.2 Conferences

- Koh, J. T. K. V., Karunanayaka, K., & Nakatsu, R. (2013). Linetic: Technical, Usability and Aesthetic Implications of a Ferrofluid-based Organic User Interface. INTERACT 2013: 14th IFIP TC 13 International Conference, Cape Town, South Africa, September 2-6, 2013. Springer Publishing Company (Forthcoming).

- Koh, J. T. K. V., Zhu, K., Peiris, R. L., & Nakatsu, R. (2013). A Hierarchy of Needs for Developing Interactive Artworks, Systems and Products. HCI International 2013 Posters' Extended Abstracts: International Conference, HCI International 2013, Las Vegas, NV, USA, July 21-26 . Springer Publishing Company (Forthcoming).

- Koh, J. T. K. V., Peiris, R. L., Zhu, K., Polydorou, D., & Nakatsu, R. (2012). Uncovering analogness and digitalness in interactive media. Proceedings of the 30th ACM international conference on Design of communication - SIGDOC 12 (p. 233). New York, New York, USA: ACM Press. doi:10.1145/2379057.2379103

- Cheok, A. D., Koh, J. T. K. V., Peiris, R. L., & Fernando, O. N. N. (2011). Mixed Reality Lab Singapore : A Genealogy of Lab Projects Employing the Blue Sky Innovation Research Methodology. CSCW 11: ACM Conference on Computer Supported Cooperative Work. Hangzhou, China: ACM. doi:10.1145/1958824.1958828

- Karunanayaka, K., Koh, J. T. K. V., Naik, E. B., & Cheok, A. D. (2011). Hall Effect Sensing Input and Like Polarity Haptic Feedback in the Liquid Interface System. Lecture Notes in Computer Science (Vol. 7040, pp. 141145). doi:10.1007/978-3-642-25167-2_16

- Karunanayaka, K., Koh, J. T. K. V., Sepulveda, J., & Tharakan, M. J. (2010). Liquid Interfaces - A New Creative Entertainment Technology. International Conference on Digital Interactive Media in Entertainment & Arts (ACE 2010). Taipei. Retrieved from http://ace2010.ntpu.edu.tw/programme.html

- Valino Koh, J. T. K., Karunanayaka, K., Sepulveda, J., Tharakan, M. J., Krishnan, M., & Cheok, A. D. (2010). Liquid interface: a malleable, transient, direct-touch interface. Proceedings of the 7th International Conference on Advances in Computer Entertainment Technology - ACE 10 (p. 45). New York, New York, USA: ACM Press. doi:10.1145/1971630.1971644

B.1.3 Patents

- Cheok, A. D., Sepulveda, J. R., Koh, J., Karunanayaka, K., & Tharakan, M. J. (2010). US Provisional Patent Application No. 61/382,374 - Liquid Interfaces - A Malleable Interface Using Direct Interaction for 3D Representation. Fenwick & West LLP Silicon Valley Center.

B.1.4 Awards

- (2012) 4th NGS Symposium Best Presenter

- (2011) James Cook University My Research in 3 Minutes Competition Silver Prize

- (2010) Conference on Advances in Computer Entertainment Technology (ACE2010) Creative Showcase Golden Award

- (2009) NUS Graduate School for Integrative Sciences and Engineering Scholarship (NGS)

B.1.5 Media Appearances

- Ng, N. (2012). Grip interviews: Jeffrey Koh. bigorangeslide.com. Retrieved March 27, 1BC, from http://bigorangeslide.com/2012/03/grip-interviews-jeffrey-koh/

- GRADUATE STUDENTS ACHIEVEMENTS. (2011). EConnEct Issue 3: Department of Electrical & Computer Engineering, National University of Singapore, (3), 17. Retrieved from http://www.ece.nus.edu.sg/econnect/Issue3.pdf#zoom=100&page=1

- When sculptures sing - through new 3D liquid interface technology. (2011). NUS Faculty of Engineering News Highlights. Retrieved January 31, 2011, from http://www.eng.nus.edu.sg/ero/announcement/web-liquid01-11-final.pdf

- Zimmermann, P. R., Cheok, A. D., Koh, J. T. K. V., Tharakan, M. J., & Nakatsu, R. (2010). International Communications Association Conference (ICA 2010) - Open Space: The Flexible Space of Interface and New Media Machines. Singapore: International Communications Association. Retrieved from http://www.youtube.com/watch?v=E_2407ltlmc

- TEDx Zurich. (2010). Jef Koh Builds Animated Interactive Liquids. YouTube. Retrieved from http://www.youtube.com/watch?v=8W9PMeWjmO4

B.2 Other Publications

B.2.1 Journals

- Peiris, R. L., Koh, J. T. K. V., Tharakan, M. J., Fernando, O. N. N., & Cheok, A. D. (2013). AmbiKraf Byobu: Merging Technology with Traditional Craft. Interacting with Computers, iws013(iws013-1). doi:10.1093/iwc/iws013

- Zhu, K., Nii, H., Fernando, O. N. N., Koh, J. T. K. V., Aue, K., & Cheok, A. D. (2013). Designing Interactive Paper-Craft Systems with Selective Inductive Power Transmission. Interacting with Computers, iws019(iws019v1). doi:10.1093/iwc/iws019

- Aue, K., & Koh, J. (2010). The Urban Rhythm. MONU Magazine #13 Most Valuable Urbanism, 2532. Retrieved from http://www.monu-magazine.com/

B.2.2 Conferences

- Cao, Y. Y., & Koh, J. T. K. (2012). A Musical Feast: How Musical Performance Using Playful Utensils Can Enrich the Cooking and Dining Experience. In J. L. Mauri & P. Lorenz (Eds.), UBICOMM 2012, The Sixth International Conference on Mobile Ubiquitous Computing, Systems, Services and Technologies (pp. 196204). Barcelona, Spain. Retrieved from http://www.thinkmind.org/index.php?view=article&articleid=ubicomm_2012_9_10_10066

- Teh, J. K. S., Tsai, Z., Koh, J. T. K. V., & Cheok, A. D. (2012). Mobile Implementation and User Evaluation of the Huggy Pajama System. IEEE Haptics Symposium 2012 (pp. 471-478). Vancouver, Canada: IEEE. Retrieved from http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=6183833

- Samani, H. A., Koh, J. T. K. V., Saadatian, E., & Polydorou, D. (2012). Towards Robotics Leadership: An Analysis of Leadership Characteristics and the Roles Robots will Inherit in Future Human Society. In J.-S. Pan, S.-M. Chen, & N. T. Nguyen (Eds.), Intelligent Information and Database Systems (pp. 158165). Kaohsiung, Taiwan: Springer Berlin / Heidelberg. doi:10.1007/978-3-642-28490-8_17

- Wei, J., Cheok, A. D., Martinez, X. R., Tache, R., Choi, Y., Koh, J. T. K. V., Peiris, R. L., et al. (2011). FoodGenie. SIGGRAPH Asia 2011 Emerging Technologies on - SA 11 (pp. 1-1). New York, New York, USA: ACM Press. doi:10.1145/2073370.2073392

- Wei, J., Wang, X., Peiris, R. L., Choi, Y., Martinez, X. R., Tache, R., Tzu, J., et al. (2011). CoDine: An Interactive Multi-sensory System for Remote Dining. 13th ACM International Conference on Ubiquitous Computing. Beijing, China: ACM New York, NY, USA. doi:http://dx.doi.org/10.1145/2030112.2030116

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- Samani, H. A., Cheok, A. D., Tharakan, M. J., Koh, J., & Fernando, N. (2011). A Design Process for Lovotics. In M. H. Lamers & F. J. Verbeek (Eds.), HUMAN-ROBOT PERSONAL RELATIONSHIPS: Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering (Vol. 59, pp. 118125). Berlin, Heidelberg: Springer Berlin Heidelberg. doi:10.1007/978-3-642-19385-9_15

- Choi, Y., Cheok, A. D., Halupka, V., Sepulveda, J., Peris, R., Koh, J., Xuan, W., et al. (2010). Flavor visualization: Taste guidance in co-cooking system for coexistence. 2010 IEEE International Symposium on Mixed and Augmented Reality - Arts, Media, and Humanities (pp. 5360). Seoul: IEEE. doi:10.1109/ISMAR-AMH.2010.5643293

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B.2.3 Reports

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- Koh, J. T. K. V. (n.d.). An Interview with Roshan Lalintha Peiris. ACM Computers in Entertainment Website. Retrieved from http://cie.acm.org/articles/in terview-roshan-lalintha-peiris/

Appendix C

Declaration

I herewith declare that I have produced this dissertation without the prohibited assistance of third parties and without making use of aids other than those specified; notions taken over directly or indirectly from other sources have been identified as such. This dissertation has not previously been presented in identical or similar form to any other English or foreign examination board. The dissertation work was conducted from 2009 to 2013 under the supervision of Professor Ryohei Nakatsu at the Keio-NUS CUTE Center, Interactive and Digital Media Institute, NGS Graduate School for Integrative Sciences and Engineering, National University of Singapore.

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