First Year Report:

Studying Engaging Natural Interaction at Home

By: Masitah Ghazali

Supervisor: Prof. Alan Dix

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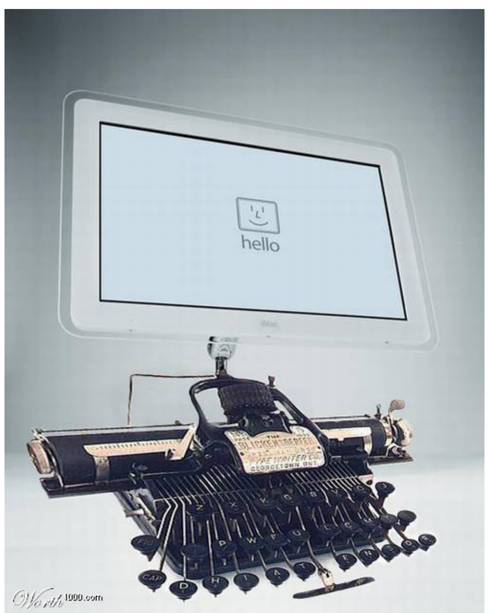
Abstract

In today's world, we could find and see a plethora of computational objects at almost everywhere in our surrounding, be it at the workplaces or at home. Nevertheless, interacting with tangible objects, which includes both physical and logical aspects, seems to be something that people still struggle with. In addition to this, the domestic setting is different from the workplaces, thus a new understanding of domestic settings is a pre-requisite before we can bring today's technology to the home. This report presents a proposal for tangible products within a home-setting project. This entails studies of physical affordances, tangible products, domestic settings and engaging user experience in order to comprehend the issues of related areas and thus to discover the 'best' ways to design novel tangible devices and to introduce technology in the home. This report also contains a work schedule in order to complete the project. The aims of this project are to uncover design principles for physical interaction to design novel tangible devices, and to propose 'methods' for bringing domestic technologies to the home. Results from this project will include a number of artefacts of tangible object/device that is applicable for home usage.

Introduction

Witnessing a plethora of computational objects in our surrounding, and using them in our everyday life, have marked the era of ubiquitous computing. Their existence has indeed makes our daily activities easier, simpler, and even more interesting. However, interacting with computational objects can sometimes be difficult to manipulate. And when this occurs, affordance is the first thing that comes into our mind.

Affordance concept has been a major influence on how things should be designed 'correctly', which this was first introduced by a psychologist Gibson (1979) and later to the Human-Computer Interaction community by Norman (1988). By incorporating affordance, and engagement of experience that exist in both physical and tangible user interface, we are trying to unearth the natural interaction of the mundane physical devices to what we believe could help us to design novel devices. Enormous potential of technology that can be deployed within domestic settings has inspired this study to relate the application of physical/tangible work to home environment.



Merging, literally, the old and the new? We will soon find out how a device of the 21st century should be designed (unknown source).

This report consists of five chapters. Below are the brief summaries of each chapter.

Chapter 1 focuses on user experience and engagement, and the various ways to get to know the users. This is important because we felt the ubiquitous computing has slightly changed the view and methods of gathering user information. Thus, this chapter looks at various approaches of how to design user experience.

Chapter 2 mainly describes the physical and tangible interaction. We first elaborate affordance concepts, which this is followed by descriptions of physical and tangible interfaces frameworks. These frameworks prove to be a good way to stimulate creative ideas for exploring possible ways of manipulating devices.

Chapter 3 briefly explains the work that has been taken place, and examples of, technology appliances and utilisation at home. In addition to this, it also elaborates the process of bringing technology into the home, which includes amongst other things, the routine activities, communication and display at home, and interactive home building procedure. We will see how domestic setting is a distinct domain from the workplace, thus require a rather different approach in order to bring the technology to the home.

Chapter 4 elaborates a number of work programs that has been carried in the past twelve moths. These include studies of understanding user experience and engagement, and, natural interaction of both physical and tangible devices. The studies have successfully provided insights namely, what contributes to engaging user experience, and, how physical design can assists the design of novel tangible devices.

Chapter 5 would be the heart of this report. This chapter puts the three identified areas of interests into perspective. This chapter also consists of PhD aims, PhD proposal and project plan schedule. The project plan is presented in Gantt and PERT charts.

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Chapter 1: On User Experience

For the past decade, user experience has been identified as one of the vital areas in Human-Computer Interaction. If we are to design a system, the information about the users would definitely benefit us in such a way that it could ensure the provision of the best user experience. And there are various ways to get to know the users. The Usability Engineering Lifecycle for instance, consists of four steps to obtain this kind of information. The first step to be taken is to identify and obtain the Individual User Characteristics. This is followed by gathering information on Task Analysis and Functional Analysis. The Evolution of the User completes the gathering information of the users. This particular type of getting to know the user by Jakob Neilsen is widely used in software and website development (Nielsen, 1998).

Nevertheless, as we entered the world of ubiquitous computing, we have seen and learned the interaction with computers does not just bound by software and monitor screens, but goes beyond reaching technological devices and other pervasive computational items around us. Thus, the view and methods of gathering user information have slightly changed.

In this chapter, we will be looking at various approaches of how to design user experiences. First we will look at a number of frameworks and models for designing experience, and on how to make one experience more engaging. This is followed by descriptions of how engaging and elements such as fun, and enhancement, are so important when designing for user experience.

1.1 Designing for experience, and engaging experience

The first framework we will be looking at is developed by Wright et al. (2003), which is used for **analysing user experience**. The framework, which is said to be a set of conceptual tool or a language for thinking and talking about experience, focuses on the relation exists between human and technology in order to understand the user. They point out that the gist of producing the best user experience is not by designing experience, but, by designing for experience. This framework consists of two parts that combines both what contributed to an experience (four types of threads – compositional, sensual, emotional, and emotions) and what involves to making sense in experience (anticipating, connecting, interpreting, reflecting, appropriating and recounting). The framework has been proved to be a success when an experiment of buying CDs in a music store is carried out, which it was able to provide practitioners with an understanding of the concept of experience that would help them designing for experience.

The idea of **deconstructing experience**, by Dix et al. (2004), is to create an experience that is able to being the 'same' as to the original/actual experience in a different way or medium. Reconstruction of experience, which normally follows the suit, recreates the surface image in a new medium. Virtual Crackers is an example that is developed based on the deconstruction and reconstruction experience. Deconstruction takes place by unpacking what we understand about Christmas crackers, and then the same experience of pulling the real crackers is reconstructed virtually on the web. The virtual cracker, which has been online for several years, has succeeded in bringing out the 'best user experience' and has received many positive feedbacks from people.

Another way to obtain user experience is by looking at the preliminary model of user experience that has been introduced by Marc Hassenzahl (2003). This model is very much concerned with **making sense of the products**. He says at most of the time, the actual information of message of the product character is not understood or not perceived by the users. It is understood that when interaction occurs between a user and a product, an experience develops. We normally thought that this correlates with usability, in which the better the usability of the products, the better experience the user may has. Hassenzahl argues that usability concept or this widely used terminology in HCI, as something that is no more about qualitative. He then suggests a model of user experience that should be measured empirically, i.e. quantitatively. The empirical evidence, which addressed parts of the model has proved how the experience influences the way the users make sense out of a product. The experience described may involve the usage mode in a given situation, and the attribute elicits from confronting with a product. Although there is no straight forward calculation to understand the users, this model provides much insights about the process of making sense of a product. This is essential especially, again, as we interact with more and more devices in our lives.

Also emphasising on products, Overbeeke et al. (2003) claim that nowadays interaction with products has become less engaging, and believe that physicality should be reinstated. Most of today's products, they say, reflect the maker's training, e.g. software engineer resembles logic programming, and, often used user-centred design, yet this is seldom applied as they only considered from cognitive skills. Overbeeke et al. suggest the designer should also consider the perceptual-motor skills and emotional skills that will lead the product to become 'intelligent'. In order to make the interaction become more engaging, Overbeeke et al. propose the designers to create a context for experience, in which the user enjoys with all his/her sense in search for challenging experience. The designer should bring together the context for experience and the aesthetics of interaction. It is important to note that aesthetics that is used is not something to do with making the products beautiful in appearance. It should shift from the beautiful appearance to beautiful interaction, and to engaging interaction.

It is also interesting to find that Overbeeke et al. state that fun is not the ultimate goal, yet it should be the results of a good experience of the products. They have come up with ten rules to augment fun and beauty, which in result have produced very unique and interesting products that we rarely see in our everyday lives, for e.g. the rotating organiser. Products of type are challenging, thus lead to more engaging experience.

Understanding user experience in terms of **emotions** of people has brought our attention to the FARAWAY project by Andersen et al. (2003). This project, which is inspired by artistic and creative techniques rather than scientific approach, is aimed to explore how new technology might support remote communication between people in affectionate relationships. The project explores new ways of conveying presence and emotions over distance by focusing more on peoples' experience and desires rather than on the technology itself. It is proven from this project that game has the potential to transform the interaction elements into viable products and/or services.

Still with regards to emotions, Desmet (2003) takes a step further by developing an instrument called PrEmo to measure emotional responses to products. Emotions have been identified to be one of vital features that involve within user experience. To one extent, emotions would be the most influence thing that decides good, better or bad user experience. He claims emotions evoked by product enhance the pleasure, which is very useful when it comes to marketing in order to sell products. He further on points out that pleasure, or experience of fun is contributed by mixture of emotions. What is interesting about PrEmo is, when the instrument is applied between cultures, culture differences cannot be explained by product-familiarity. This result is very important especially in global marketing, which concludes the user experience can be designed regardless of the differences of individual profiles.

Indirect experience would be another way to make the user experience more engaging. Hull and Reid (2003) have carried out experiments, from which one of the great findings is, engaging experience is possible to be delivered through systems with fairly simple functionality. For example, ZapScan – scanner that scan pictures through one button interface, and display the digital picture on vertical screen, is found as very engaging and fun by the children, which this is actually made from our everyday office technology. They also stress on the positive involvement of users and artists in the design process for this complements the overall view of the system design. In addition, they propose a model that should improve the engagement of user experience. The model consists of three dimensions: challenge/satisfaction, social/interaction and drama/sensation. They continue by pointing out that it is sufficient to engage the user experience by having just one dimension of the three suggested dimensions.

In the mean while, McCarthy and Wright (2002) associate engaging with **enchantment**. In their foray to find out what hold the power to enchant something ordinary as a phone or a computer for instance, they lean on an analysis of how films can be enchanted from a famous writer and Hollywood producer, Boorstin. Boorstin share his insights by revealing the three ways of seeing, voyeuristic eye – the normal way we see things where we look to things closely and becoming bored as the newness of the thing has gone, vicarious eye – experienced through imaginative participation in the experience of another, and visceral eye – bring into harmony the experience of thrill, joy, fear and abandonment. McCarthy et al. oppose to the thought of enchantment is easy to be dismissed in the space of public appearance by giving examples of an internet store tries to enchant each customer by engaging with the identity of the shopper, and, the relationship that is between the Apple computer and Mac users.

1.2 Fun for engaging experience

Fun is another element that can ensure engaging in experience. Brandtzæg et al. (2003) believe experience that includes the element of fun is far more relevant in ensuring engaging experience, than easy-to-use in interactions between human and computers. They propose a model that consists of three elements, demands as fun, decision latitude and social support that points out the social opportunities is a strong factor to facilitate enjoyable experience. Thus, the human design model should focus more on developing the design that provide more social opportunities.

Blythe and Hassenzahl (2003), and Sengers (2003), however, oppose to Overbeeke et al. views' on usability in products to enhance engaging experience (see section 1.1). In search of defining user experience in the new perspective has led us from usability – that deals greatly with efficiency, effectiveness and satisfaction, to pleasure, emotional affect, and aesthetics of new technology. In order to design for experience, Blythe and Hassenzahl (2003) point out we must understand the experience as it relates to and differs from others. They profoundly explicate the differences of fun and pleasures. Whilst both are context-specific, fun is normally associated with being unexpected, whilst pleasure focuses on activity and a deep feeling of absorption. Fun is all about distraction, and fun as an experience is a consequence of triviality, repetition, spectacle and transgression. Pleasure on the other hand, is about absorption, and pleasure as an experience is a consequence of relevance, novelty, aesthetics and conformity. Both definitions are coming very useful when we design for experience.

Usability, easy-to-use, and efficiency are no longer in favour when it comes to user experience. Sengers (2003) who sees there is some kind of gap between the work-related tasks and non work-related also agrees on this statement. As a computer scientist herself, she points out that in Computer Science, and even in HCI itself, the focus has always been on increasing the efficiency of software or system execution. In her attempt to break down this phenomenon, she shifts the aspect of engineering experience to inter-disciplinary approach and states that fun should be part of experience in the hope that this kind of experience would exist in both work and non-work related tasks. Fun should be less about efficiency, and should be more about quality of experience. By combining computer science and cultural analysis, Sengers proposes three generic heuristics that should be taken into consideration when designing experience, especially when designing one of AI experience. The heuristics are; focusing more on shaping the 'actual', driving the 'computational' behaviour from human behaviour, and think about meaning, not information.

1.3 Conclusion

We have seen that living in today's world that is filled with ubiquitous and pervasive computational things has demanded 'new' frameworks and approaches to design for experience. In addition, products are so influential as it is capable of making the experience becomes more engaging or otherwise. Understanding emotions, fun, happiness, and enjoyment have now been taken into considerations in order to ensure a far better engaging experience.

In addition to this, two studies have been carried relating to engaging user experience. These works can be found in Chapter 4.

Chapter 2: On Physical and Tangible Devices

Interactions with devices and with other everyday things can sometimes be problematic. Every so often we find ourselves having trouble to understand how to manipulate these devices and appliances. If this problem is to remain in today's ubiquitous world, we will definitely encounter similar scenarios when interacting with ubiquitous computational devices. We believe by returning to the basic, that is to understand what makes the interaction of day-to-day appliances more natural, can enlighten us the notion of natural and comprehensible interactions of both physical and tangible devices.

This chapter first focuses on concepts of affordance that have been introduced originally from the psychological perspective before it being introduced later on in the HCI field. Besides seeing the importance of affordances in understanding the natural interaction, we also include a number of examples of tangible devices that have been developed to this day to illuminate us how interaction takes place amongst the tangible devices. We also look at some few frameworks on physical and tangible design that mostly propose a better design for both physical and tangible devices.

2.1 Affordances

Affordance concept has been widely accepted in HCI field when it is popularised by Norman (Norman, 1988). This concept is originally a work by a psychologist named Gibson who has introduced 'affordance' in his book entitled Ecological Approach to Visual Perception (Gibson, 1979). Nevertheless, to a degree, Norman and Gibson both have different ideas of what affordance really is.

According to Gibson (Gibson, 1979), affordance as attribute of an interaction design feature is what that feature *offers* the user, what it *provides* or *furnishes.* He illustrates his definition by giving an example of how a horizontal, flat and rigid surface affords support. In his perspective, affordance is reckoned with respect to the user. Furthermore, Gibson points out affordance as physical properties, which it as a physical relationship between actor and physical artefacts in the world reflecting possible actions on those artefacts. We can clearly see this type of affordance does not have to be visible, known, or even desirable.

Gibson's affordance is referred to as real affordance by Norman (Norman, 1999), which he says this unqualified term affordance is merely about physical characteristics of a device or interface that allow its operation. Norman introduces another type of affordance: the perceived affordances. Perceived affordances are the characteristics in the appearance of a device that give clues for its proper operation. He emphasizes on the point that we must understand the difference of the two, and not to use the term affordance alone. Although Norman says much of the examples in his Design of Everyday Things (DOET) book, are about perceived affordance, the two affordances have become somewhat lost due to lack of emphasis of the two affordances.

Following is a table that briefly illustrates the differences of affordance concept by both Gibson and Norman:

Gibson's Affordances • Offerings or action possibilities in the environment in relation to the action capabilities of an actor • Independent of the actor's experience, knowledge, culture, or ability to perceive • Existence is binary – an affordance exists or it does not exist
Norman's affordances • Perceived properties that may or may not actually exist • Suggestions or clues as to how to use the properties • Can be dependent on the experience, knowledge, or culture of the actor • Can make an action difficult or easy

Table 1: Gibson's and Norman's Affordances (adapted from McGrenere et al., 2000)

We often refer to affordance concept, especially in our design work, be it by Gibson or Norman. Nonetheless, ambiguity do appear somewhere along the line even within the HCI community itself. Gaver, McGrenere and Ho and Hartson, are amongst who have attempted in clarifying the ambiguity exists in affordance.

Gaver (Gaver, 1991) refers affordances in design as a way of focusing on strengths and weaknesses of technologies with respect to the possibilities they offer to people who use them. He separates affordances from the perceptual information that specifies affordances (see Figure 1), which allow us to consider affordances as properties that can be designed and analyzed in their own terms. Referring to Figure 1, if the user has the perceptual information, the affordance may perceive to be existed. He extends the concept of Gibson and Norman by showing how complex actions can be described in terms of groups of affordances, sequential in time and/or nested in space, showing how affordances can be revealed over time, with successive use actions, for e.g. in the multiple actions of a hierarchical drop-down menu.

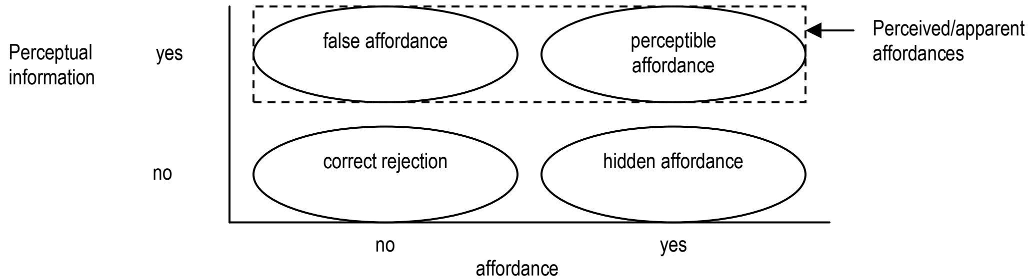

Figure 1: Separating affordances from the perceptual information that specifies affordances (adapted from Gaver, 1991)

McGrenere and Ho (McGrenere et al., 2000) aim to clarify the affordance concepts for effective communication among researchers and practitioners and make a connection to usability design. McGrenere and Ho first analyse both Gibson and Norman work before discussing the importance of affordance in terms of design, and specifically in the area of software design. Both of them disagree to a claim that Norman made about a scrollbar is a learned convention and implies that it is not an affordance. They also make a clear distinction of usefulness versus usability when it comes to designing affordances and designing the information that specifies the affordances. According to McGrenere and Ho, usefulness of a design is determined by what the design affords, whilst the usability of a design can be enhanced by clearly designing the perceptual information that specifies these affordances. Below is an illustration of a framework of affordances for design that both McGrenere and Ho propose, in which by moving along the diagonal line could give improvements in design.

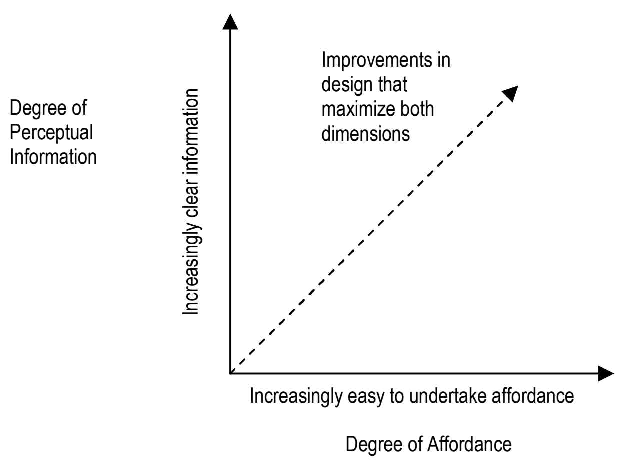

Figure 2: Representing the affordance and the information that specifies the affordances on a continuum (adapted from McGrenere et. al., 2000)

The most recent work on affordance has been carried out by Hartson in his paper Cognitive, Physical, Sensory and Functional Affordances in Interaction Design (Hartson, 2003). In brief, Hartson refers Cognitive affordance to what Norman described as Perceived affordance: that helps users with their cognitive actions. Physical affordance refers to what Norman defines as real affordance, which is about helping users with their physical actions. Helping users with their sensory actions illustrates the sensory affordance, whilst functional affordance ties usage to usefulness. Hartson, in his paper, emphasises on the design of physical affordances as he says almost no one mentions of this. Design of physical affordances is about design of physical action part of usability, easy-to-use in the form of high performance and productivity for experienced and power users as well as to help disabled users achieve maximum efficiency in physical actions. And this is why Hartson introduces 'sensory affordance' along with cognitive and physical affordance. Hartson concludes his work by outlining guidelines for considering these kinds of affordance together in a design context.

The guidelines contextualised design as nexus of affordances roles. The first notion that Hartson points out in the guidelines is a positive association of affordance roles as structured HCI design guidance. He describes how the four concepts of affordances; cognitive, physical, sensory and functional, might guide designers. By taking an example of designing an interactive button, the designer can first begin by asking the button functional affordance. This then assists the designer to support cognitive affordance in the button design. Next, the designer will consider how physical affordance can support the button design. Finally, all of these would lead the designer to consider sensory affordance to support physical affordance. This affordance theory can guide especially the design of HCI artefacts. Nevertheless, Hartson stresses the concept of affordance does not offer a complete prescriptive approach to interaction design but does suggest the value of considering all four affordance roles together in design of an interaction artefact by asking.

Secondly, Hartson points out the fact of false cognitive affordance that always misinforms and misleads the users. Therefore, it is very important for the designers to use cognitive affordance with caution. The users encounter errors when cognitive affordance falsely telegraph physical affordances. Gibson use the term 'misinformation in affordances' whilst, Draper and Burton use the term 'affordance bugs' (Draper et. al., 1993).

Finally, in Hartson guidelines, he comes up with User Action Framework (UAF) that is developed based on Norman's Interaction Cycle, and by connecting other interaction design concepts in the domain of design and analysis for usability. What is different between UAF and Interaction Cycle is its hierarchical structure knowledge base. Below describes how the Interaction Cycle transforms into UAF framework.

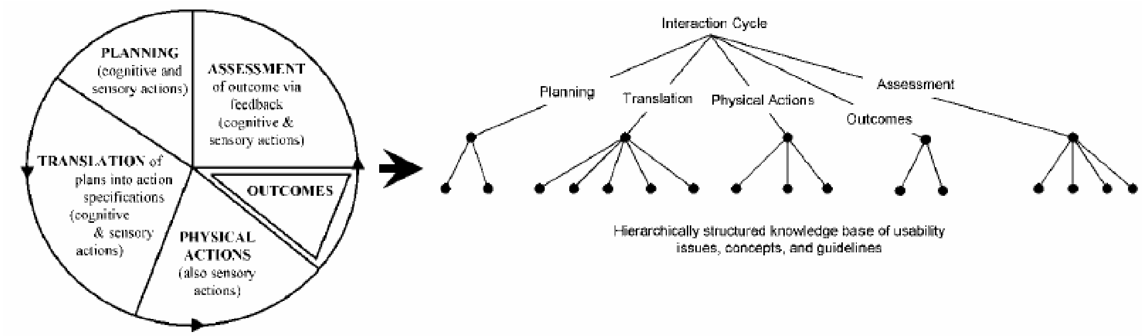

Figure 3: Basic kinds of user actions, plus Outcomes, from the Interaction Cycle as top-level structure of UAF, a usability knowledge base (adapted from Hartson, 2003)

The re-definitions of affordance that they introduce have made quite a significant impact in HCI as the analysis successfully clarify what have not been well understood before. For once we may think these work would create more ambiguities as each tries to bring 'new' concepts, yet it is far from it. It does not because these works actually broaden our views on affordance, and the similarities found resulted in some sort of affirmation of what affordance really is.

2.2 Tangible devices

Before we proceed with tangible devices, it is best for us to first grasp what Tangible User Interface (TUI) really means. TUI goes beyond Graphical User Interfaces (GUI) that instead of a generic screen, mouse and keyboard, TUI uses specific physical form to represent and manipulate the pieces of data in the system. TUI are often be in a simple and transparent mechanical structures, so the user can instantly know how to operate them and what they mean just by relying on existing knowledge. TUI also often entails the augmentation of existing physical objects by adding digital meaning to the objects and their manipulation. TUI can also be viewed as the further evolution of GUI in which TUI increases the realism of the objects by allowing the user to interact even more directly with them.

In this section we will see examples of tangible devices that have been developed to this date. We are not going to judge whether they afford natural interaction, or whether to decide the physical design is good or bad, but merely to see what each device has to offer.

MIT Tangible Media Group is one of the most active research group, leads by Professor Hiroshi Ishii, which has produced a number of ongoing researches and made a significant number of breakthroughs on tangible devices. Below are few examples of tangible devices carried out by MIT Tangible Media Group:

2.2.1 The metaDESK

The metaDESK (Ullmer et al., 1997) is a platform that demonstrates the interaction of "tangible user interfaces" supporting physical interaction with digital information through manipulation of physical objects, instruments and surfaces. Having inspired by the idea to push back from the GUI into the real world, the team focus on the use of tangible objects, which are of real physical entities which can be touched and grasped. In addition, they instantiate TUI elements by mapping GUI widgetry into physical space. For example, GUI "icons" as TUI "phicons", GUI "menus" as TUI "trays" and GUI "handles" as TUI "phandles".

The components that makes of the metaDESK, like the desk, active lens – flat panel display, and passive lens – fiber-optic-bundle that acts as an independent display, are designed according to what they understood about the use of physical affordance within TUI design. For instance, the active lens is designed in such a way that it suggests more than just as a magnifying lens as it also looks, acts and is manipulated like such a device, hence supports user's natural expectations.

The prototype called Tangible Geospace has been developed to demonstrate the use of metaDESK. The Tangible Geospace consists of several physical objects and instruments for interacting with geographical space that sit in a translucent holding tray on the metaDESK's surface. Picture below illustrates the Tangible Geospace:

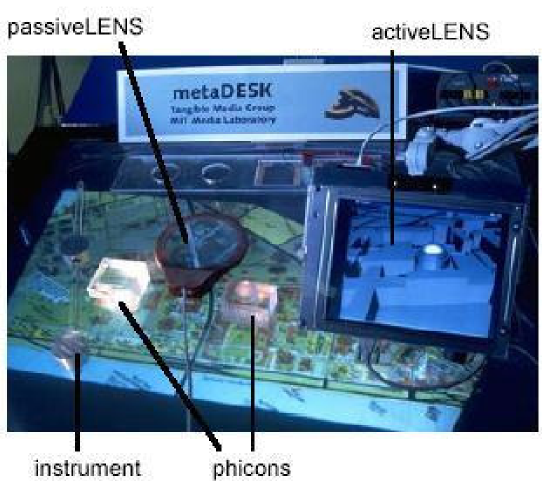

Figure 4: Tangible Geospace Prototype (adapted from Ullmer et al., 1997)

2.2.2 The Actuated Workbench

The Actuated Workbench (Pangaro et al., 2002) is a device that uses magnetic forces to smoothly move objects on a table surface in two dimensions. This project tries to overcome the common weakness in interactive workbench system, which is the output of physical interaction that is normally restricted to digital information rather than physical manifestations of the information itself. The Actuated Workbench is intended for use with existing tabletop tangible interfaces that provides an additional feedback loop for computer output, and that helps to resolve inconsistencies that otherwise arise from the computer's inability to move objects on the table.

The developed system is able to move multiple pucks at the same time, without the need to build larger pucks. It can also recreate a range of user gestures with the pucks, and it is silent as its actuation mechanism has no moving parts. It however could not build the pucks as entirely passive devices because of the IR LED and battery that needed for vision tracking.

Among the applications that Actuated Workbench has to offer are of some basic GUI functions and some higher level applications. The applications on basic GUI functions, which is carried out by extending these functions into the physical domain, include Search and Retrieve function to respond to user query that wants to keep track of every data item on the table, Sort function that organizes pucks on the table according to user-specified parameters, History and Undo function which allow the user to physically move the pucks back to their positions before the last change, and show the user the exact sequence of movements the user had performed. Teaching and Guiding function teaches the user something about interacting with the system through physical gestures. This is because the workbench has the ability to recreate users' gestures with the pucks.

For the higher level applications, the functions comprise Remote Collaboration that offers multiple users to make simultaneous changes to the system, and, when users are collaborating remotely, a mechanism for physical actuation of the pucks becomes valuable for synchronizing multiple physically separated workbench stations. Simulation and Display for Interacting Objects of the Actuated Workbench is very useful and helpful in the scientific visualization of complex mechanical systems. For instance, the workbench can be used to teach students to understand about charged particles by taking the examples of the pucks' behaviour. Entertainment application enables the Actuated Workbench to be used as an enhancer of physical dimension to computer entertainment. It provides a significant improvement to games' devices, for instance, motorized chess, making them more flexible for a variety of games.

2.2.3 Senseboard

In this particular project, the grid concept is applied for organising information on tangible interface. It combines the benefits of physically manipulating note cards or sticky notes, with arranging icons on a computer with a graphical user interface, into a single system.

Senseboard (Jacob et al., 2002), a new platform and tangible user interface, is built to carry out the tasks of manipulating, organising and grouping pieces of information. Senseboard is made of a vertical panel, mounted rather like a portable whiteboard. Pucks – small rectangular plastic tags (see figure 5), can be placed into these cells and stick there magnetically. When a puck is moved, the board sends the identity and the grid location of each of the pucks in the grid to a computer on a serial port via a small RFID tag inside the puck.

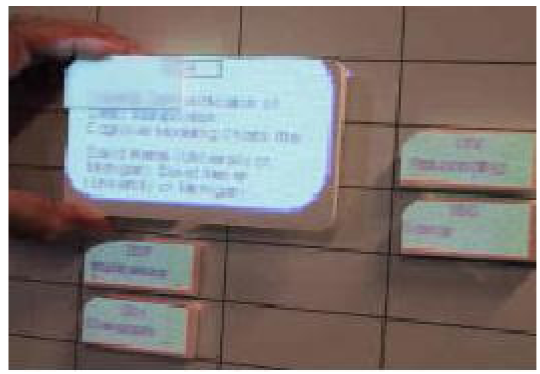

Figure 5: Pucks

As the team overall goal is to make the data items tangible and graspable, as if the data were "tangible bits", they carefully identify data that each puck carries and commands to operate the pucks. Taking the example of organising conference papers, each magnetic puck represents each item with some information about the paper projected into its smooth white surface. By so doing, the user can simply move the puck around the grid to organise the papers. In order to assist the user to complete the task, each command is embodied in a special puck, shaped differently from the others, that can be momentarily placed over a regular data puck to operate on it like a rubber stamp.

Below are the commands the Senseboard provides:

- View Details – allows user to view additional information about a given item by placing the command puck over the puck to be viewed
- Group – allows the user to take several items and combine them into a new, single item, representing the group by first arranging the items on the board to form small groups, then placing the command puck over the first item to be grouped together
- Ungroup – this command operates analogously and explodes a displayed group item back into its component items

- Type-in – allow the user to enter new data from keyboard
- Copy or Link – displays the original data item and the copy with a line drawn between them by placing the command puck on the original item and then on a blank puck where the user wants the copy
- Export – allows user to convert the final arrangement of the items into a digital form that can be exported to another program

It has been proven that tangible interface can provide a more effective means of organising groupings, and manipulating data than either physical operations or graphical computer interaction alone.

2.2.4 Water Lamp and Pinwheels

Having envisioned the space we inhabit will become an interface between humans and digital information has inspired the team to develop two ambient fixtures that present information within an architectural space through subtle changes in light, sound and movement. Based on the metaphor of natural physical phenomena, Water Lamp and Pinwheels (Dahley et al., 1998) have been designed to create physical water ripples created by raindrops of "bits" and spin in a "wind bit" respectively.

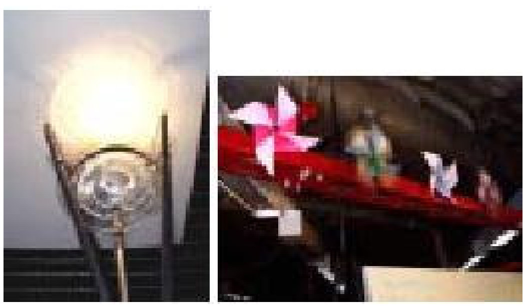

Figure 6(a) Water Lamp,
Figure 6 (b) Pinwheels

The ripples of the Water Lamp are created not by physical raindrops, but by "bits" (digital information) that have been realised with computer-controlled solenoids tapping the water. The three solenoids that are mounted above the water tray are controlled through a single circuit board, which when actuated the solenoids tap on the surface of the water in the tray, resulting ripples in the waters surface. The ripples effect are enhanced by a light that shines upward through the tray and produces changing patterns of light and shadow projected onto a ceiling.

The Pinwheels spin in the "bit wind" at different speeds based upon their input information source. The Pinwheels is composed of folded fibreglass mounted on the shaft of a small DC motor. Pulse width modulation controls the speed at which the motors spin.

The ambient fixtures have the potential to create subtle and informative reactive environments through the application of displays integrated within our architectural spaces. In addition we ought to learn issues like mapping of information to the physical motion, persistence in the space and thresholds between background to foreground, that arise in designing and testing ambient fixtures.

2.2.5 Illuminating Light

Illuminating Light (Underkoffler and Ishii, 1998) is about working with an optical design tool with a luminous-tangible interface. The user uses the tool to move physical representations of various optical elements about a workspace, while the system tracks these components and projects back onto the workspace surface the simulated propagation of laser light through the evolving layout.

Illuminating Light is a working application of the Luminuous Room infrastructure. As the system heavily exploits the advantage of control via graspable implements, and its success act as direct representations of the ‘real thing’, has allowed Illuminating Light to provide constant visual feedback in a form that is already intrinsic to the simulation’s real-world counterpart. The system uses the holography technology to projects components on the surface by using the facilities of an I/O Bulb. The holography requires six basic elements in order for it to be executed with the Illuminating Light system; a laser, mirrors, beamsplitters, lenses, a ‘holo-object’, and the holographic film plate itself, which all of these elements clearly must be in the size that can be easily graspable.

The given examples have shown us that those functionality that seemed to be impossible to have before are now possible, by merging the physical and the digital together. In addition, most of them consist of and convey very rich information - directly, or subtly.

There are also other research teams who are actively involved in the tangible research interest. To name one, in the UK, they have Equator[1] research group, with its interdisciplinary research collaboration focuses on the digital and physical interaction.

[1] EQUATOR URL http://equator.ac.uk

2.3 Frameworks

In this section we will look closely at some frameworks that have been outlined from the aspect of physical and tangible interfaces design. We will see from the described frameworks that natural interaction or affordance inevitably plays an integral part in the design stage.

2.3.1 Sensible, sensable and desirable

The Sensible, sensable and desirable (Benford et al., 2003) framework proposes a guideline for designing physical interfaces from the movement perspective. It aims is to encourage designers to consider potential mismatches between sensible, sensible and desirable movements from an early stage and to see them as opportunities, as well as problems. Following is an illustration of how the framework should be seen and thought of, i.e. space as the design problem or opportunities.

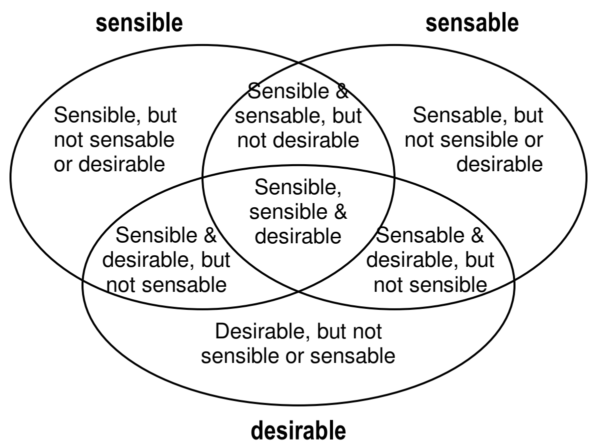

Figure 7: Sensible, sensible and desirable model (adapted from Benford et. al., 2003)

Sensible is about movements that users might normally be expected to carry out. Anything that is outside this range is said to be less sensible as this is considered to be interacted only in unexpected way. For instance, it is sensible to hold PDA with one or two hands while standing, and it is less sensible when carrying the device above your hand, although it is possible to do so. They observe that different properties movement, e.g. accuracy, speed, ranges of movement, contributes to what makes the movement sensible. They also observe the distinction between sensible and less sensible movements emerge from combination of factors. For example, the physical form of its interface (its size, shape, weight, joints) and the form of the interface that constrains possible movements (physical cables constrain rotation). Therefore, they strongly encourage the designers to explicitly reflect in details on what they often implicitly believe to be sensible and imagine the less sensible movements that might occur.

Sensable, on the other hand, defined as movements that can be measured by the computer. For instance, the capabilities of a GPS sensing position that can be integrated into PDAs, vary to its flavour (e.g. normal or differential) and the quality of the receiver. Furthermore, poor delay and low accuracy occur when using budget receivers. Location also contributes towards GPS capabilities, as GPS coverage is very low indoor, at the urban or underground.

Desirable is defined as movements that are required by the application. For example, some applications of tangible objects may require them to be rotated on a surface, whereas others may assume a fixed orientation and only require repositioning. In other words, there may be movements that would be desirable to the application but that are not sensible and/or sensible, and other movements that are sensible and/or sensible but that are not desirable.

The application of the framework involves four steps as described below:

i. Analyse sensible movement, which this includes consider the likely effects of physical form, scenarios that could result in less-sensible movements and impossible movements
ii. Analyse sensable movements by identifying all of the known limitations and how we could fool sensing systems
iii. Analyse desirable movements
iv. Try finding possible movements to fit each using the model

We believe this framework can support both the analysis of designs and the generation of new ideas. Rejecting many new ideas led the designers to better understand the core nature of the interface. To name a few, Augurscope II, Drift Table and Interactive flashlights are amongst the projects which apply this framework.

2.3.2 Ambiguity

Ambiguity (Gaver et al., 2002) framework is something that we don't come across everyday, as ambiguity seems to be the nemesis of the goals of HCI: usefulness and usability. Ambiguity, as they argue, is a resource for design that can be used to encourage close personal engagement with systems, which in other words, the relationship between person and artefact. Allowing ambiguity allows designers to engage users with issues without constraining how they respond, enable users to find their own interpretations and make a virtue out of technical limitations by allowing peoples' interpretations to supplement them.

They give four examples that describe how ambiguity can appear in technological systems. Projected Realities is about a system intended to help increase the presence of older people in a large Dutch housing estate by presenting slogans and images to reflect concerns the older people felt about the area, and their pride for the complex physical and cultural environment. Desert Rain is a mixed reality performance in which the players have to explore the virtual world within a specific period of time. By making the boundaries deliberately ambiguous provoke the participants to re-evaluate the boundaries between reality and fiction, and between the real and the virtual. The Pillow displays electronic information in an impressionistic, ambiguous way by containing an LCD screen embedded in a plastic brick that displays blurred simple geometric shapes. The shapes join with processed sounds to indicate passing electromagnetic information from various devices, e.g. mobile phones. The Home Health Monitor gives feedback about the home's emotional, social and spiritual health on a daily basis. By monitoring peoples' activities in the house provides people with a systematic but inconclusive foundation that reflect the emotional state of their home.

The examples described highlight the fact that ambiguity is a property of the interpretative relationship between people and artefacts. This distinguishes ambiguity from related concepts such as fuzziness or inconsistency, which these are attributes of things, whereas ambiguity is an attribute of user interpretation of them. In addition, they distinguish three principle kinds of ambiguity: ambiguity of information, of context and of relationship.

Tactics for using ambiguity are outlined to help designers recognise, understand and use ambiguity, which these entail the three principles that has been mentioned. Tactics are described as follows:

i. enhancing ambiguity of information
   - use imprecise representations to emphasise uncertainty
   - over-interpret data to encourage speculation
   - expose inconsistencies to create a space of interpretation
   - cast doubt on sources to provoke independent assessment

ii. creating ambiguity of context
   - implicate incompatible contexts to disrupt preconceptions
   - add incongruous functions to breach existing genres
   - block expected functionality to comment on familiar products

iii. provoking ambiguity of relationship
   - offer unaccustomed roles to encourage imagination
   - point out things without explaining why
   - introduce disturbing side effects to questions responsibility

Although ambiguity would not be everyone's choice, the most important benefit it has to offer is it gives designers to suggest issues and perspective and considerations without imposing solutions.

2.3.3 Tangible User Interface (TUI) framework

TUI framework (Koleva et al., 2003) is used to classify a representative selection of existing TUI systems, which are based around the degree of coherence between physical and digital objects. Links between physical and digital objects are described in terms of a set of underlying properties: transformation, sensing, configurability, lifetime, autonomy, cardinality and link source.

The framework puts together the degree of coherence of TUI categories, which are described in terms of the seven properties, alongside with the physical-digital link. Degree of coherence distinguishes the different types of tangible user interfaces by rating the relationships between physical and digital objects along the coherence continuum. We can see whether the physical and the digital artefact are seen as one common object that exists in both the physical and the digital domain, or whether they are seen as separate but temporarily interlinked objects. Following is the level of coherence and property setting put together:

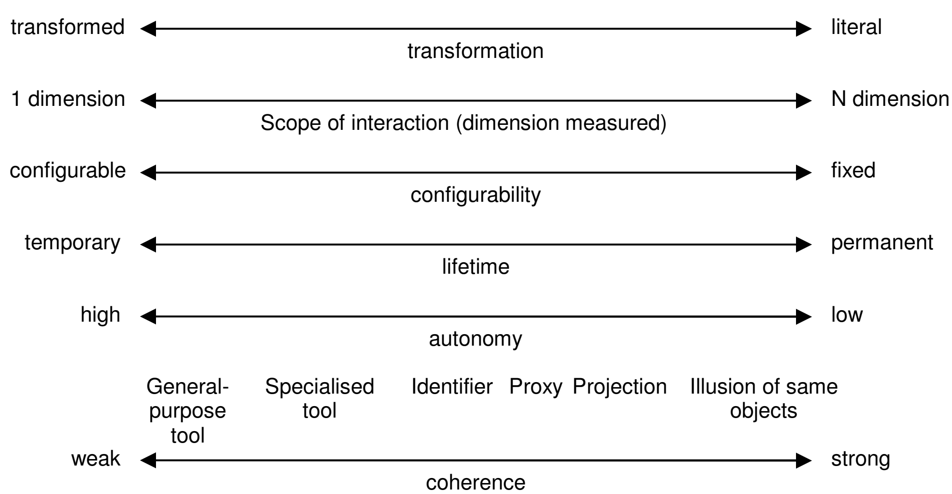

Figure 8: Property settings and level of coherence (adapted from Koleva et. al. 2003)

They suggest that in general, the strength of the relationship and the coherence perceived between two linked objects increases as we move towards one extreme of the property settings. As we move towards permanent lifetime, low autonomy, larger number of interactions, and fixed configurability, the linked object will be perceived more and more by users as being the same thing. And in this case, the physical objects are said to be having illusion of same object which projects strong coherence of physical and digital link. This link property can then be used to classify the current TUIs.

The framework that has been used to classify current TUIs has raised a number of broad implications for the field of tangible interaction. The links between the physical and digital also has given much insight on asymmetry of the links that lack of tangible interfaces that react to changes in digital information, configuration of the links involved and the need for the users and developers to understand the nature of the link between the two.

There isn't a single doubt when people say frameworks are important in guiding one design. However, one framework may not be adapted fully in one application. The designer might use pick-and-mix approach in order to suit with their system. The framework sometimes be applied in the early stage and some may not. It is also can be used to seek for more opportunities, that can be thought of beforehand by the designers.

2.4 Conclusion

A number of attempts in seeking the closest meaning to affordance, or what affordance really is, complement each other's work that resulting to a broader and better understanding the concept of affordance. Affordance also is the 'root' to most of all tangible devices, and frameworks given in this chapter, with the exception to ambiguity framework. It is also fascinating to find that development of tangible devices can sometimes be initiated merely by inspiration, besides fulfilling the aims, either to complement the best of physical medium, to enhance the tangible feedback or to make the space a subtle interface to convey digital information. The frameworks have proven to be one way to stimulate creative ideas, or to guide our thinking the unthinkable, the less sensible, or the impossible.

Chapter 3: On Domestic Setting

Domestic setting is a context which we believe could bring the best out of both engaging experience and tangible objects put together, and we think it has so much potential for the technology to be deployed in this setting. However, when we are talking about bringing the technologies into the home, it requires a lot of effort, as Gaver (2001) points out,

> *"There is a danger that as technology moves from the office into our homes, it will bring along with it workplace values such as efficiency and productivity at the expense of other possibilities."*

Hindus (Hindus, 1999), who shares similar view point, argues the importance of home-related research on technology, and emphasises the differences between researching homes and researching workplaces. Therefore, the new dimension of domestic technology necessitates new methods and frameworks in order to develop the appropriate technologies.

Studies in domestic environments have always been on of the areas of interests under the ubiquitous computing research work in Lancaster University. Many of the projects related to domestic settings have been carried out in the association of Equator. Some of the work projects are Load Sensing Table (Equator, 2003) and Smart Pin (Equator, 2003).

Industrial companies have also started looking into the area of domestic settings. Some even have taken a step further in inventing new merchandise for home usage. For example, companies such as Electrolux has invented a refrigerator called Screenfridge (Electrolux, 2004). It is a combination of refrigerator and computer, which can be used ranging from sending messages and email, food management to digital cook book.

This chapter first reviews how an ethnography team from Equator set foot into domestic settings to capture and assimilate patterns of activities going on inside the homes, and how this could possibly support the technology. The second area that we will look at is from the perspective of the architectural itself - how by having the intention to build a so called smart-home could give such a significant impact on house planning, and, the design of homes for special target groups. Finally, we will see some devices and products that have been developed to be used within the domestic settings, and devices that focus on aesthetics rather than their practical functionality that seem to be perfectly suit within domestic settings.

3.1 Pattern-based studies, ethnography, communication and display

The interdisciplinary research nature of Equator has led one of its team to carry out studies in domestic settings. They are interested in the use of pattern-based approaches as a means of structuring the on-going analysis of ethnographic material. What it means by ethnography is not to collect a large number of studies of targeted activities, yet, it is to examine one or two instances of their situated occurrence in observable and reportable details of their occurrence (Crabtree et al., 2002c).

They believe the adapted **pattern-based framework**, which they develop based on the original work by Alexander, is valuable for structuring and presenting ethnographic fieldwork and supporting the development of new technologies for domestic settings. The framework, which consists of 9 cores feature (Crabtree et al., 2002a), is hoped could meet its objective, which is to identify generic patterns of social action and embedded technology at homes. They emphasise on the aspect of 'Typifications' – the descriptive patterns, which is central to design. The pattern of framework that they were trying to identify is to support the design process, by providing resources, which are the key activities, interactions and technology, and which are of related to places. Routines activities have been elaborated in very detail in their paper (Crabtree et al., 2002b).

Having given the framework, they further on pointing out the three steps in order to apply the framework. The first step to take is to find the real world pattern in domestic routines. This is followed by identifying patterns in the fieldwork, and, lastly by presenting patterns of domestic life. The framework has been proved to be of importance for the designers as its ability to erase the legacy issue of the unnecessary research of incorporation of technology into the home from day-to-day activities, as it is 'thought' this action may well be eschewed as the home will be utterly transformed in the future. In addition, the pattern framework successfully supports the elaboration of the design space through the identification discrete application areas.

Another aspect that has been studied within domestic settings is **communication**. It is revealed that communication to be richly organised by household members. For instance, communications of mails, bills, and cards, coming into and going out of the home shows the existence of flow of traffic that this designs an ecological system of communication (Crabtree, 2003). It is important to note that the system is subject to the architectural and aesthetic contingencies of places, owing to the fact that houses are not uniform, and neither are furniture and decorations. Crabtree points out stable organisation features of the system consist of 'ecological habitat' (places where communication media lives), 'activity centres' (places where communication gets done and media get used), and 'coordinate displays' (places where communication media are situated to facilitate collaboration). One of his important remarks is that domestic space is not merely a container for communication but a resource actively exploited by inhabitants to organise and accomplish communication.

Hemmings et al. (2003) then explicate further on **coordinate displays** by focusing on supporting 'phatic' communication – i.e., on supporting communication that is mediated by words, whether spoken or written and co-located or distributed. By using mail use in the home to show phatic communication, it is verified that phatic communication is itself mediated through the social construction of visual displays that support the at-a-glance coordination of practical action and the management of domestic affairs. For instance, placing certain mails at the corner of kitchen table requires the head of households to take note and thus take action on the mails. This study helps the development of email for home use as it highlights the need to support workflow and task management when designing technologies for the home through the development of networks of ecologically situated and mobile displays that support the visible and timely flow of information around the home.

In relation to the 'coordinate displays' above, the study has been extended to understanding the **act of displaying** within domestic spaces. Again by using mail use in the home, they elaborate the role of such displays play in social coordination and collaboration (Crabtree et al., 2003b). They begin by saying the act of displaying or interfacing goes on to provide for the coordination of work. Their studies, which is said to be 'system-specific', tied to the settings they elaborate. They articulate the various types of display, e.g. windowsill, noticeboard, etc., that are turned into actions or activities by members, e.g. handling mail, paying bills, in particular types of setting, e.g. student home, family home. From this study, it has given an insight, especially for the designers to think about how to merge the digital (what we desire to do) with the physical. In addition, this study in particular, has enabled the team to furnish answers to the foundational questions of CSCW research.

Below are the four presented questions and answers (adapted from Crabtree et al., 2003b):

1. What displays already exist in a setting?
   This consists of a variety of different displays constructed by members to coordinate the work of a setting. Coordinate displays are constructed out of the specific material technologies to-hand in a setting.
2. Where are displays currently located?
   Just where coordinate displays are constructed in a setting depends upon the dual contingencies architecture and aesthetics the setting is physically composed of.

3. How are displays situated in a setting?

   The coordination of a setting's work is made possible by the distribution of coordinate displays across the ecology of the setting to form a distinct network.
4. Why or for what purposes displays are constructed?

   Ecologically distributed networks of coordinate displays are constructed to enable the collaborative management of work in, and flow of work through, a setting.

Still inspired with the idea of merging the digital with the physical, Crabtree et al. (2003a), carry out a study on calendar use in domestic settings to illuminate design space and inform design reasoning. They take three scenarios that each describes different notion of calendar, which are: calendar is an accountable social object, calendar use relies on essential accountable work-practices, and, collaborative access underpins negotiation. From these findings they suggest three things that should be taken into consideration when moving the use of calendar (Groupware Calendar System, from workplace) to the home (adapted from Crabtree et al., 2003a):

- Anywhere, anytime: electronic calendars should be made available to collaboration in the physical space of the home and off-site, anywhere, anytime as occasion demands
- Computer-mediated communication and interaction: devising negotiation protocol to enable members to negotiate their schedules through the active use of the technology
- Data sharing and distributed collaboration: enable users to control and manage data sharing through the specification of roles and other appropriate criteria

From their findings of routine activities and technology uses in domestic environment, they develop an analytical framework and a set of concepts to inform design within domestic settings (Crabtree et al., 2003c). The framework, which draws attention to the three different properties of ecological habitats, activity centres and coordinate displays, as described earlier, makes visible the social organisation of communication and the distributed arrangements of collaboration to communication. From the framework, we are able to identify the places where communication 'gets done' and where a host of different communication media are manipulated and used, both through the routine sequences of action. The framework also highlights prime sites for situating new and emerging technologies in the home environment. For instance, when the occurred activity overlap places – coffee table to read mails, write letters, talking on the telephone, etc., we can always see a variety of different media employed across a range of different sites (laptop, PDA, mobile phone, cordless telephone).

3.2 Building evolution and design homes for specific groups

A study is carried out to look into the evolution of buildings, due to the development of digital technologies for future interactive domestic environments. The work by Rodden et al. (Rodden et al., 2003) emphasises on understanding a variety of research approaches that are used to understand the domestic. These include ethnographic studies of the routine activities, longitudinal studies of the ways in which technological are used, and design based method that highlights the need to be sensitive to a broader set of cultural values within the home, e.g. cultural probes.

There is also diversity of devices for domestic setting. Key approaches of the various categories define different interaction techniques used by different devices. The first approach: informative appliance often uses touch screens as its interaction technique. Interactive household object approach incorporates interaction into the form of the object, e.g. cups are augmented with temperature sensors. Whilst the third approach, the augmented furniture, mediates its interaction through sensors detecting actions with the furniture.

It is also important to take note of the different domestic environments that would be embodied with interactive properties. The new forms of context sensing environment focus on exploiting sensors in order to infer the particular context of interactions. Embedded interactive technologies, on the other hand, focuses on developing technologies that make the fabric of the environment more interactive.

Different kinds of digital infrastructure should also be taken into consideration. A flexible infrastructure is important to underpin interactive arrangements, and therefore, it is vital to ensure the cost of adding a device must be low to let devices be easily introduced into the setting, and the devices must be able to exploit their surrounding and the other devices to provide an interactively rich experience. The existing infrastructure we have today includes Jini, UpnP and Cooltown.

Having aware of various necessities of developing future domestic settings has led the team to consider a framework of building process. Based on the process of developing existing building – this includes the six generic S's, site, structure, skin, services, space plan and stuff, the framework includes the diverse set of skills involved, the different representations used and the issues of ownership and responsibility in managing the process.

Some other studies of designing homes are carried out on a specific target group, for e.g. the disabilities, and the elderly people. DIRC, under its activities 7 – ubiquitous computing in the home, has studied various issues that includes, designing residential spaces for people with disabilities (Dewsbury et al., 2001b), designing safe smart home systems for vulnerable people (Dewsbury et al., 2001c), designing smart home technology for disabled people (Dewsbury et al., 2001a), and deconstructing and rebuilding the home for life to assist older people in their homes (Dewsbury et al., 2002).

3.3 Devices and products

i) Playing with the bits

We begin by looking at a lightweight component model that is developed based on user-oriented framework to support the user reconfiguration of ubiquitous domestic environments (Humble et al., 2003). The model allows the users to interconnect to a range of devices onto it by accessing an editor that support users in doing this. To be able to interconnect a range of devices is essential to support the continual change of technology in domestic settings. By wirelessly connected to the network, the user can uses the editor to discover available ubiquitous components. The ubiquitous components are presented in the form of jigsaw pieces that can be dynamically recombined.

The fundamental aim of components is to ensure the convergence of the physical and the digital environment. The components which are later referred to as transformers, consists of three main classes of transformer component: physical to digital transformers, digital to physical transformers, and digital transformers.

There are three approaches to use the model. The simplest approach would be to combine three jigsaw pieces in order to meet the particular needs. For instance, when noticing a grocery item is missing from a cupboard, the user only needs to first choose Grocery Alarm piece – reports the missing item, then followed by the second jigsaw piece AddToList, and finish it off by choosing SMSSend jigsaw piece to send SMS to the phone. The components can also be integrated to larger devices such as the webcam and displays, and to link sensors and devices to more abstract and complex entities.

ii) Casablanca

ScanBoard and Intentional Presence (IPL) Lamp have been designed as social communication devices that could be incorporated into households and family life (Hindus et al., 2001). IPL consists of Curtain IPL and Lampshade IPL, which both of these devices allowed users to indicate their availability for communication and to control the appearance of the device to a limited extend. Scanboard device acts like a noticeboard except it can be accessed by many users, and is automatically updated to show the latest configuration of the selected boards by means of shared database system.

From this study, they point out five prominent conclusions. It has been proven, yet again, that home is a distinct domain that household priorities and concerns are quite different from the workplace. Secondly, media spaces in home will span a wide range with the development of simpler, lightweight and essentially asynchronous interactions despite of media-rich, high-bandwidth and multimodal devices. Thirdly, social communication is a suitable research topic with the fact that household technology is still considered as underexplored research area. Fourthly, express just enough meaning, but not too much to maintain the simplicity. Finally, social interaction should not be imposed on users to prevent existing social obligations on the users' part.

iii) Home Use Product Development Techniques

Blythe et al. (2002) have proved the techniques to be a good way to harness our creativity to come up with unique ideas for domestic products. The techniques, which are known as technology biographies, identify three important aspects: past, present and future, that involve situations and everyday objects. Past consists of two sets of questionnaires, Technology Tour and Last Time Questions that involve areas of tension, conflict, humour, pattern, routine and disruption. Personal history is asked to dig answers of the past that entails nostalgia, loss and celebration. For the future element, Guided Speculation and Three wishes that are about hope, fear, scepticism, and problems addressed are asked.

The processes, concerns and problems of domestic life obtained from the participants are then used to develop illustrative product suggestions to inspire or provoke designers. One of the appealing suggestions from the pilot study is to build a flat wall mounted washing machine for quick daily washes, instead of having to wait until weekend to do weekly washing due to the fact that labour saving devices, which is washing machine does not save.

iv) Slow technology and aesthetics

If in the workplace everything has to move faster as they always refer "time is money", we expect things to be a bit laid back when we get home. And it would be even better if at the same time we don't lose out on what has been happening at home whilst we are at work. We would like to highlight 'slow technology', which is part of Johan Resdtröm research work. According to Resdtröm, slow technology is a design agenda for technology aimed at reflection and moments of mental rest rather than efficiency in performance. And when the right expressions of *writing*[2] and *reading*[3], are given to slow technology, it will create a basic collection of examples that can support systematic investigation of the aesthetics of computational technology as material for the design of everyday things (Resdtröm, 2001). Although slow technology seems to be similar to calm technology (Weiser, 1996), slow technology differs in such a way that it focuses more on the subject of promoting moments of reflection, whilst calm technology on the other hand is more about technology in the periphery that provides us with contextual information.

Following is a list of displays and devices that have been developed that require people to reflect in order to make sense or to be 'informative'.

Displays and Devices	**Reading**	**Writing**
Fan house: a 3x3 matrix wooden rack with a fan mounted in each cell, and layers of thin fabric are hanging in front	As patterns of fabric in motion	As patterns of information controlling nine fans
Fabric door: Fragments of fabric in different colours and textures are hanging in the ceiling, enclothing the entrance to a room	As a pattern of fabric in motion and indirectly as a pattern of accelerometer information	Walking through the fabric
Lamp foot: Lamp foot is a floorlamp with the lampshade placed just above the floor, with dry autumn leaves laid out on the floor around and below the lampshade. Inside, there are four small fans that will transport the leaves out to on the floor in different patterns	As pattern of autumn leaves on the floor	As patterns of information controlling the fans
Paper recycler: A matrix of electronic fans are mounted on a rack, covering the bottom of a cardboard box. Filled with paper fragments, the box and the fans create a display based on the movements of a large number of small pieces of paper in different colours, sizes, shapes and mass	As patterns of different pieces of paper in motion	As patterns controlling the fans
Sail house: Paper sails on wooden sticks are placed in each cell of 3x3 matrix wooden rack, one for each column. Each mast may be used to turn the sails in a column in different directions, each sail can also be manipulated separately	As patterns of papers sails set in different directions and indirectly as patterns of light intensities	Setting up different patterns of paper sails
Chest of drawers: A small wooden chest with six drawers has a mirror attached to the bottom of each drawer. The mirrors reflect light inside the drawer when opened. In the ceiling of each drawer there is a light dependent resistor for measuring the intensity of the reflected light	As pattern of drawers pulled out to varying extents and indirectly as a pattern of light intensities	Pulling out and pushing in drawers
Block bench: A small wooden bench with three tracks. There are four movable wooden blocks, with proximity sensors facing the tracks. Four metal cylinders are placed between the blocks as sliders. The Block bench can	Directly as a pattern of blocks and sliders on the bench and indirectly as a pattern of distance information	Setting up different patterns of blocks and sliders on the bench

[2] Submitting information or data to the system

[3] How people read information represented

represent four positions in three different scales		
Tray: A rectangular metal tray is hanging from the ceiling in four wires to place objects like marbles, nuts or even coffee cups that create patterns when sliding as the inclination is changed. Four stepper motors with gears are used to heighten or lower each wire in very fine steps so that the height and inclination of the tray can be precisely adjusted	As pattern of moving things on the tray	As patterns of information controlling four electrical stepper motors

Table 2: Displays and Devices (adapted from Resdtröm, 2001)

The displays and devices described above can be used in four different settings, in which in all of the settings require us to learn to master the art of reading from the various displays, in the same manner as we note washbasin is wet, or a drop of milk on the table. The settings are listed below:

1. Simple display settings: can be used to describe history, reports and balance
2. Simple communication settings: can be used to describe the use of furniture, for e.g. by connecting Chest of Drawers to Lamp Foot, to enter a room, and to use a doorbell
3. Complex settings: by connecting several of the displays in various ways to fine tuning, browsing and mixing
4. Extreme settings: this pushes the invisibility to the extreme by imagining wherever there is expression, there is possible information, by fully integrate the displays and devices with the rest of the interior

3.4 Conclusion

From this chapter we have learnt that domestic setting is a distinct domain that is different from the workplace, hence require rather different approach to bring the technology to the home. A various number of work programs focusing on domestic environment have been carried out, and these includes adapted pattern-based ethnography practise, which concerns routine activities, communication and display at home, interactive home building procedure, and what are best for us to consider when developing devices for home usage. To be able to convey information digitally around the house is one of the ways to tackle the question of bringing the technology into the home.

Chapter 4: Own Work

Having undertaken literature review on various topics as described in previous chapters, we have then carried out a number of studies related to the topics. Besides putting our understanding to test, each study tries to explore ways to apply what we have understood in different perspectives.

4.1 Engagement and Fun

Prior to this study, we felt that the element of fun must not be excluded when we design for experience in order for us to ensure the experience is engaging. We carry out a case study in attempt to answer whether fun is, or is not, a factor that guarantees engaging experience.

We begin by identifying the four possible relationships of engagement and fun: engaging and fun, not engaging and fun, not engaging and not fun, and fun and not engaging (see Appendix A figure 1), before making transformation onto experiences of each category to analyse the relationships of the four categories. It has been proven that the act of transforming one experience from one type to another is not an impossible thing to do, providing that we understood the experience and are able to identify the salient features that could mutate the experience.

Nonetheless, there have been some few issues arise related to the mutation process that entails notions of what it is fun in an experience, internal and external motivations that capable to influence one's experience, and having more than one experience at a time (see Appendix 1 section 2.3 for details). In addition, from the transformation/mutation process, we have carefully analysed each transformation in order to seek the critical points – the points where the changes occur (see Appendix 1 section 3). By discovering these points have given us insights on how we can 'control' the 'scale' of engaging and fun experience.

We then turn the findings into a generic heuristics that would be beneficial especially in the development of design products as the heuristics are able to enhance the engaging and fun experience. The heuristics includes the aliveness of a product, the cardinality of interactions one has, challenges of the experience and motivations (see Appendix 1 section 4).

From this study, we are able to explore that engaging experience can exist even without the element of fun, which contradicts to what we have thought before. The critical points have made us understood that characteristics can be changed in a quite flexible way to something better (enhancement), if not to worse.

4.2 Quantitative study on engagement

A study has been carried out to compare user engaging experience in two different environments: one using personal computer (PC), and the other using mobile computing device (PDA). This study is carried out with another PhD student, Fariza Hanis Abdul Razak. Amongst the questions we seek to answer of this study are; what are the differences of engaging experience if we use different systems, and by different type of users, what are the elements that support engagement, etc. (see Appendix B, section Objectives).

The four participants, who involved in this study, were given a short task for them to carry out using both PDA and PC. The methods that we used for data gathering on user engaging experience include observation – observing the users as they interact with the applications, and interview – open and structured questions to obtain more insight data on user engagement.

From this study, we are able to confirm that novices are more engaged than the experts within the same computing environment. For example, when novice users interact with a PDA, they were very careful in almost every task they carried out as to avoid, or, minimise errors. Between the two different environments, regardless the experts or the novices, engaging experience exists when the tasks they encounter are unfamiliar or new and/or challenging.

We can also confirm that there are four elements or components that support engagement. Good feelings towards the application help the participants engage in their tasks more, for example, a novice user who was very nervous as she never encountered using a PDA before, felt much better and much in control once she successfully completed the first task. Good interface designs also support engagement as these help the users to explore better. Also, new challenging tasks support engagement for expert users, whilst the novice users' engagement experience can be supported if they encounter with new computing device, although the tasks assigned are basic. It is also worth to mention that confusion may occur amongst the novice users if their previous knowledge does not conform to using the new application. Once the engagement occurs, the users will be in control and learning will take place, thus, increases or improves the performance.

There are three fundamental things we have identified resulting from this study. Firstly, the engagement is able to put user in control, and leads the users to learning. Secondly, understanding the users in terms of their background, experience and perception towards computers are essential in the design process, and, thirdly, the findings are very useful in aiding the design of mobile learning interface.

4.3 Natural interaction principles - Understanding New from Old for Novel Device Design

This work which we have carried out is in relation to affordance, physical and tangible objects. Our main interest is to understand what exactly makes the physical interaction and of the physical-logical mapping comprehensible and natural in the hope that we could one day design novel devices that exhibits natural interaction. In order to achieve this, we focus on two categories: intentional but implicit, and the more explicit interaction, by studying the real physical controls on everyday-used artefacts.

We introduce four additional aspects, or principles, of interaction besides the strong affordances the physical devices exhibit that enables the user to understand how to manipulate the device. These additional aspects exploit the physical form of the device to inform the users' interaction with the logical function they control (see Appendix C and D):

<u>Exposed state:</u>
The underlying logical state of the system is exposed by their physical state, thus, the direct mapping between the two enable the user to immediately apprehend how to control the device. For e.g. a light switch.

<u>Hidden state:</u>
This would be the contrast of the exposed state, and normally is assisted with extra indication or information to help the user to manipulate the device. A good example is the twist control of a speaker that has no intrinsic on/off position given by its physical shape.

<u>Inverse action:</u>
This action is extremely important if the user does not have a perfect knowledge of the physical-logical mapping. Inverse effects, like turning a speaker volume anti-clockwise to decrease volume, exploit natural physical inverse actions.

<u>Compliant interaction:</u>
When a physical control lets the user to sets the program, and at the same time the system turns the control itself as the program advances, it is said the physical control exhibits compliant interaction, and also exhibits a symmetry of interaction. Expert users can thus easily learn how to fine tune the device, like in washing machine, and take control by skipping parts of the program, starting in unconventional places, and so on.

We then extend our work by using the rich knowledge of implicit in the design of everyday-used artefacts to uncover principles that can be used in the design of novel tangible interfaces (see Appendix C and D). Besides elaborating further on the four principles – which we introduce and briefly elaborate about haptic feedback, we also use what we have found of the rich knowledge implicit in the design of everyday-artefacts to uncover principles of the novel tangible interfaces design. We apply the success factors from the analysis to a novel device called a Cubicle (Sheridan et al., 2003).

Cubicle that we used in our study is a small cube that is used in seating area. With each side is labelled with one of the possible feeds into the display: TV tuner, laptop cable, etc, the user can simply turn over the cube to select a particular feed. Cubicle with labelled on each side exhibits a good visible states, in which the one-to-one mapping between the visible state of the Cubicle and the logical state of the situated display is very clear. In addition, it is also possible for the number of states to be increased up to 24 states by considering the orientation when using the Cubicle. Alternatively, the number of states can also be increased by painting one half of the Cubicle or one corner only (see Appendix C, page 6).

Unlabelled cube, however, would be the simplest decoration to exhibit inverse action. By having no distinguishable states, the cube can be used in the same way as a mouse or joystick, where only the relative movements like rotating, and twisting, are important, and not the absolute location. Tipping would also be a good inverse action for the Cubicle. For instance, if by tipping forward is selecting a choice from a menu, tipping backward should be the reverse action (see Appendix C, page 6).

Compliant interaction wouldn't be as easy as it seems if we try to apply on the Cubicle. This is due to the fact that the Cubicle is predominantly passive and untethered input device. One suggestion would be by having a small display on each side, which when the user rotates a particular face upwards, the display could then change over time under applications control (see Appendix C, page 6).

This study is then extended by examining a wider range of tangible interfaces in the context of a tangible user interface framework as we believe the good design of the everyday-appliances should offer benefits for the design of tangible devices. In addition to this, we also have added tangible transitions and bounce back, in our design principles for physical interaction and extensively elaborated the first four principles (see Appendix D, page 15).

We first look at existing tangible devices that we thought to embody the principles, and seek where in the design space of tangible interaction the principles can contribute to improve the design. For instance, Marble Telephone Answering Machine (Crampton, 1995) exploits exposed state principle, while Storytent (Fraser, 2003) exploits hidden state principle to intentionally hide the logical function to make the experience more interesting. Senseboard (Jacob et al., 2002) has been described earlier in section 2.2.3, is one of examples that exploits inverse action, whilst Rototack (Wrensch et al., 2000) conforms to compliant interaction principle.

We then explore the findings from the above task against the TUI framework's properties and categories (see Appendix D, figure 5). We found that every tangible device of proxy, projection and illusion of same objects categories, which also exploit exposed state and compliant interaction have strong physical-digital link. While tangible devices from identifier, specialised tool and general-purpose tool categories, which also exploit hidden state have the weak side of the physical-logical interaction. Meanwhile, tangible devices from identifier category moving towards the illusion of same objects category exhibit strong physical-digital interaction (see Appendix D for more details).

From this study, we have been able to come up with two fundamental things: the nature of naturalness and levels of coherence principles, and, guidelines for tangible control. These findings would benefit us all when developing and designing tangible devices.

4.4 Conclusion

This chapter elaborates works that have been carried out in the past twelve months. The studies of engaging experience have given us insight about how engaging experience can actually be achieved with various ways. For instance, challenges and good feelings towards something contribute to engaging experience. Our extensive study about physical interaction, by first looking on how we manipulate and interact with everyday appliances, has deepened our understanding on natural interaction. The findings have enabled us to explicate rich definitions of natural interaction. Thus, we use these to explore the interaction of tangible novel devices, with the hope that the interaction will be more fluid and natural.

Chapter 5: PhD Proposal

Having investigated these three domains; engaging user experience, natural interaction in both physical and tangible aspects, and technology within domestic settings, has enabled us to identify a focal point that could sew the three areas together. If we recap the issues that have been discussed in the previous chapters that vaguely related to one another and the work that we have carried out, we would be able to see that ***product*** is the key to all three areas.

Engaging user experience

- User experience can be engaging if the user can make sense of the products (page 2)
- Elements that can make the experience more engaging includes: emotions, enchantment, sensual, and fun (page 3,4)
- Indirect experience of interacting with simple devices increases engagement (page 3)
- Deconstructing experience that mimics the actual experience also increases engagement (e.g. virtual cracker) (page 2)
- The product that is of new technology should be pleasurable, emotionally affective, and have aesthetics values (page 2)
- Aliveness character of a product, the cardinality of interactions one has, challenges of the experience and motivations – from the study, are the heuristics than can be used to make the experience when using a product more engaging (page 30)
- Engagement leads to learning and is able to put the user in control of a product or medium (page 31)

Physical and Tangible devices

- Naturalness of interaction within physical devices (physical-digital mapping) should be applied in the design of novel tangible device (page 32)
- Affordance concept is essential when it comes to interacting with product(s) – four important aspects that we should think of, according to Hartson (Hartson, 2003) are: cognitive, functional, sensual and physical (page 6-9)
- It is best to combine both the practicality of physical and tangible (page 13)
- Enhancing tangible devices with tangible feedback (page 11-13)
- The relevant frameworks guides our mind to think the unthinkable of what a product can offer (page 16-18)

Domestic environment

- The pattern-based framework that focuses on activities and routine in the home, identification of communication, and act of displaying objects at home, enable us to identify how and what type of technology can support human within domestic settings (page 22-24)
- Devices or products that are to be used in the home should be simple, easy to use, flexible and compatible to support continual change (page 26, 27)
- Devices should be able to subtly convey information without having the user to interact with the device, e.g. slow technology, aesthetic values (page 27-29)

Following diagram summarises how 'product' is linked and related to the three main sub-areas that we have studied earlier. Of each sub-domain consists of key notions of how a 'product' shall be designed to obtain the desired 'product'[4].

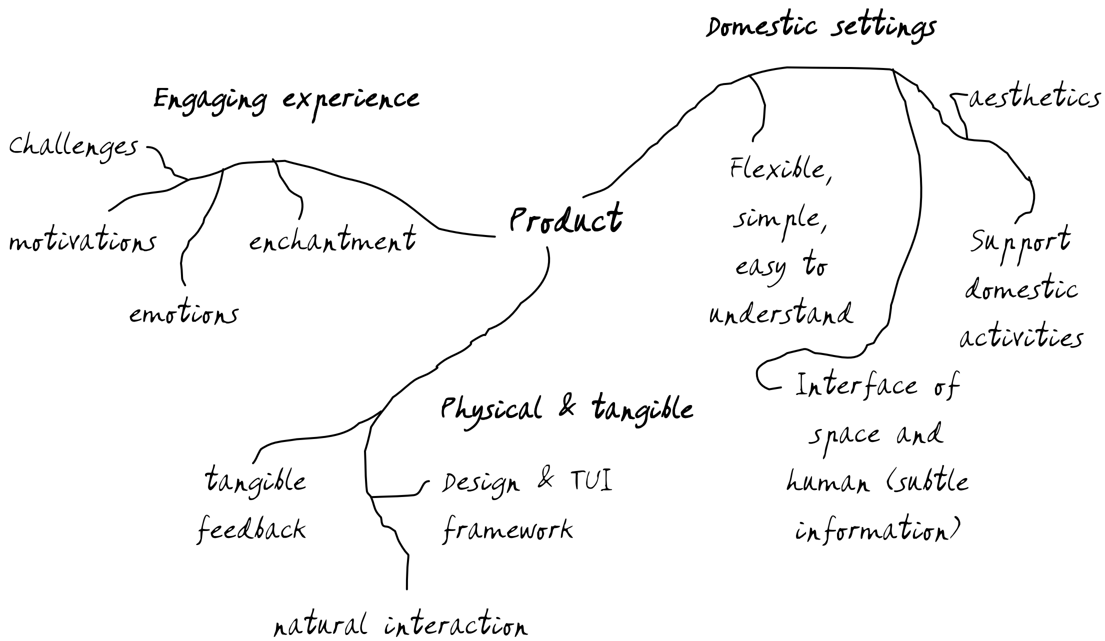

Figure 9. Product mind-mapping

5.1 PhD aim

My aim is twofold, (i) to continue investigating the naturalness in interaction on tangible devices and, building and assembling tangible objects (artefacts) by abiding the principles to prove them

4 Beyond this point, *product* will be referred to as *artefact* as it delivers more profound meaning in which it derives from detail and meticulous studies.

right, (ii) to investigate further the question of what and how the technology (tangible devices from previous) can be brought into the home.

Issues arise during evaluation of products, which are very critical to this research, would highlight the potential for further development and thus illuminate what is the most sensible thing to have within the domestic environment, without neglecting the principles of natural interaction and good engagement.

5.2 Research Methodology

This research entails literature studies on theories, frameworks, and current projects mostly of tangible devices and domestic environment. In addition to this, this research also includes development and testing of building tangible devices, which are followed by testing and evaluation.

Below is a list of the proposed activities of the project, which is also presented in the form of PERT and Gantt charts.

Activities	Resources	Duration (month)
Lab-based practical	IIL Hardware Lab, Designing Embedded Systems books	6
Refine natural interaction – in relationship to and distinction with previous work, etc.	Equator	6
Develop sample using natural interaction principles, testing	IIL Hardware Lab, Equator	6
Investigate tangible devices at home	RCA meetings and projects, Interior designer(s) meetings, Other current projects (DIRC, HEAT)	6
Develop domestic application, testing	IIL hardware lab	6
Evaluation	Participants, location	4
Writing	Reviews, testing, evaluations	5

Table 3: Proposed Activities

Figure 10. PERT chart

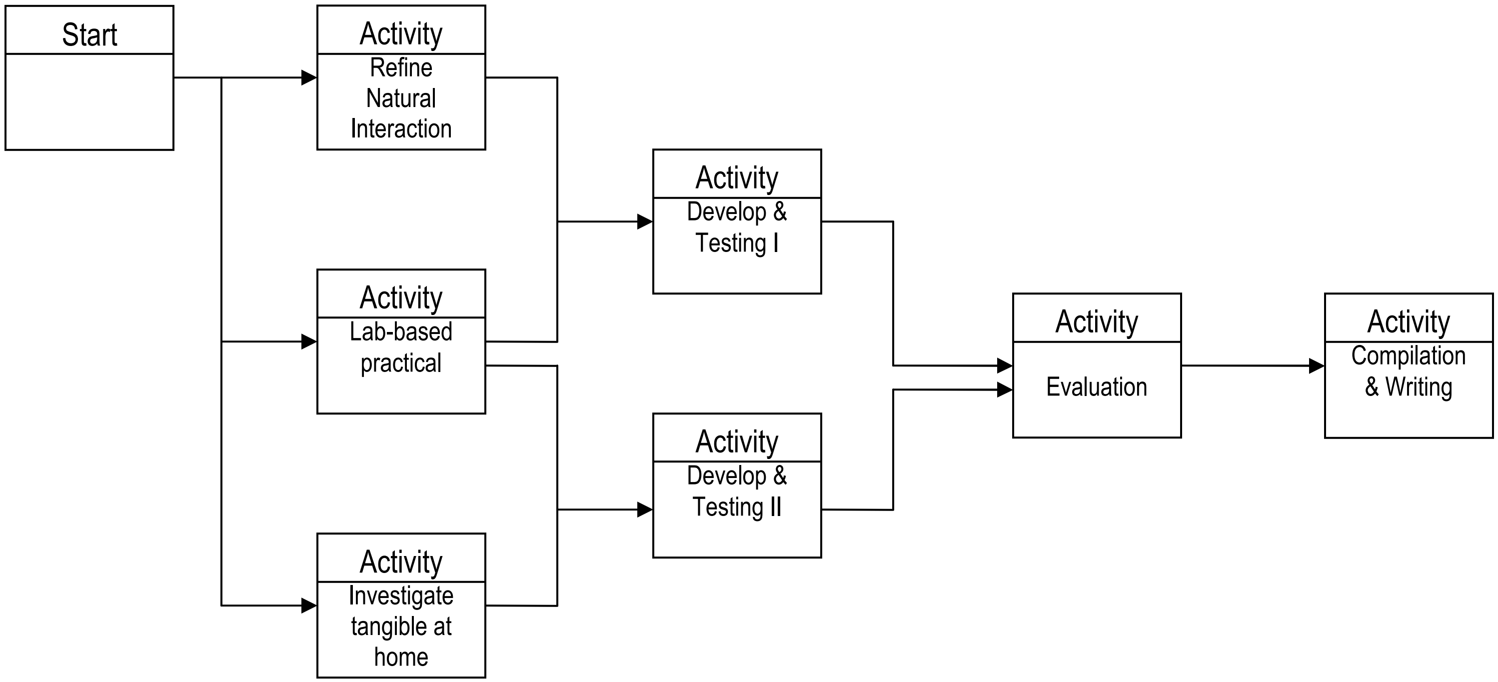

Figure 11. Gantt chart

Activity/Month	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July
Lab-based practical																		
Natural interaction																		
Develop & Testing I																		
Tangible at home																		
Develop & Testing II																		
Evaluation																		
Writing																		

5.3 Beneficiaries

This research would certainly benefit several groups of people and certain research areas. The computing society, especially the teams who focusing on tangible research, would be benefited as the findings of the natural interaction principles has proved to be successful in assisting the development and design process to enhance the naturalness of interaction of novel tangible devices. In addition, this research would also benefit the community who is working within the domestic settings, be it of computing society, home designers or artists, in such a way the results of this research broaden the perspective of domestic technology deployment and utilisation in the home.

5.4 Conclusion

This chapter puts each domain research area into perspective, thus enabling us to identify the focal point of this research: the product. This chapter also consists of the proposed activities, their resources and a schedule in order to get the project completed. Tentatively, the project will take 17 months to complete. The outcomes of this project are hoped to be of benefits, especially within the domestic settings, as this area is still in its infancy.

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