“It’s the little things that matter"

A ready-to-assemble SMARTKIT to help people organize consumables at home
by hacking furnishings through a do-it-yourself approach

By

Ling Ding

A thesis exhibition presented to OCAD University
in partial fulfillment of the requirements for the degree of
Master of Design in the Digital Futures

Toronto, Ontario, Canada, April, 2017

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A ready-to-assemble SMARTKIT to help people organizing consumables at home by hacking furnishings through a do-it-yourself approach

By: Ling Ding, MDes Digital Futures, OCAD University, 2017

ABSTRACT

Democratization is broadly applied in material design and technology innovation, but little is known about democratic design in the digital context. Inspired by the practice of enchanted objects, this paper applies user-centered design as the primary research methodology to investigate what kind of democratic digital solutions might help Millennial-aged consumers streamline their home routines. SMARTKIT is a hacking toolkit created to allow individuals with little hacking ability to enchant the ordinary functionality of home furnishings and endow them with new capabilities which provide personal and social services that monitor and manage home consumables. By adding easy and affordable DIY enchantment, the democratically-designed SMARTKIT will help empower users to design the future of their homes in an accessible and affordable way that fulfills the unique requirements of each user.

SMARTKIT makes the little things matter.

Keywords: Democratic design framework, IOT, DIY for HCI, Enchanted object, Mobile and ubiquitous computing, Smart object, Intelligent furniture, Ambient intelligence.

ACKNOWLEDGEMENT

Firstly, I would like to express my sincere gratitude to my advisors Professors Sellen and Tindale for the continuous support of my thesis research, for their patience, motivation, and immense knowledge. Their guidance helped me in all the time of research and writing of this thesis.

Besides my advisor, I would like to thank the rest of my thesis instructors: Professor O'Mahony, Professor Ladly, and Professor Mclntosh for their insightful comments and encouragement, but also for the hard questions which led me to widen my research from various perspectives.

My sincere thanks also goes to Dr. Wyman and Raze Safaei, who provided me tremendous help on my Master's degree study at OCAD University since I joined here. I also would like to thank a group of amazing people Nicole Knibb, Kennedy Chiejina, Hammadullah Syed, Mudit Ganguly, without them this design would not have been polished.

I thank all my peers, friends and participants for the stimulating discussions and participating, but also for the shared sleepless nights spent working together before deadlines, and for all the fun we have experienced in the last two years.

Last but not the least, I would like to thank my family: my parents and my husband and my son for supporting me spiritually throughout writing this thesis and my life in general.

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER 1 – INTRODUCTION

1.1 Personal Story

I am a mother who has a very demanding three-year-old son, and I am also a graduate student, and, concurrently, hold a consultant position. My husband works in a full-time capacity as well. Time is always short for us and, as a consequence, our home is always a mess. The problem seems pretty trivial, but it is a huge issue in my daily life. We seek for the new smart technology to streamline the home. There is no affordable and available smart device to deal with daily disorganization such as searching for items like shoes, socks, and small items. Disaster happens when we misplace something in a rushed situation. We both enjoy technology and adopt new technology early. However, where I seek out new and novel product innovation, my husband, a computer engineer, is concerned more about the price and perceived value of goods, especially when adopting new smart devices. The argument is how to convince each other what is the right time and right price to purchase new smart devices for the family. For example, when should we buy Google Nest to help manage our home. Even after we installed the equipment, we struggled for control over the technology that is supposed to make our lives easier. My husband is the person who sets up our home technology, but our challenge now is control—which of us should regulate

the device in a way that benefits us both? If my husband leaves for work and sets Nest up in ECO-mode, the temperature of the house is set to save energy consumption. If I work from home, I have no control over this setting, and the room gets too warm or too cool to comfortably work in. What if we could make something specific to our family needs?

1.2 “Must Have" versus “Nice to Have."

We are not the only couple who were trapped by the question of technology as something that is "nice to have" versus something we "must have." According to Business Intelligence Report, the smart home market is stuck in the 'chasm' of the technology adoption curve, in which it is struggling to surpass the early adopter phase and move to the mass-market adoption phase (Greenough, 2015). Geoffrey Moore, in his book "Crossing the Chasm," illustrated that the most difficult step to surpass this chasm is to make the transition between visionaries (early adopters) and pragmatists (early majority) (1998). The reason is that, compared with visionaries, pragmatists believe in the evolutionary not the revolutionary, looking for productivity enhancement rather than novel products (Mohr, et al., 2009). For the majority of potential customers, smart home technology is something "nice to have," not yet considered a "must have." Few people are willing to pay for unnecessary smart home devices as they do not yet hold personal and product value. The smart home market has not expanded since

2007 despite research firms predicting that the smart home market will reach $100 billion by 2019 (Briodagh, 2015). The truth is that just 14% of households worldwide are connected to the Internet, and 5% of families own smart devices(Economist,2016). The transition toward smart home technology from an early adopter to mass market industry depends on the creation of widely accessible, easy to use applications of the technology, rather than purely focusing on the technology itself (Perlmutter, 2015). The way to draw the market growth is not merely connecting the home devices but creating tremendous inherent value associated and complementing devices with lifestyle, which must be demonstrated through ease of use directly to customers (Perlmutter, 2015). Smart home technology also needs to address the shared environment of each household and who lives there, such as the elderly, children, and pets. It is tricky when the residents and their differing needs are plurals, but the control is singular (Higginbotham, 2015). The way to draw the market growth is not merely connecting the home devices but creating tremendous inherent value associated and complementing devices with lifestyle, which must be demonstrated through ease of use directly to the customers (The internet of thing, 2016).

Another key consideration for any smart home system is how well it fits into an existing family's current home. Making the transition towards a smart home relies on the availability of simple, low-cost retrofit technologies that leverage existing investment in home systems is going to be critical in reaching a

wider audience of potential customers (NextMarket Insight, n.d.).

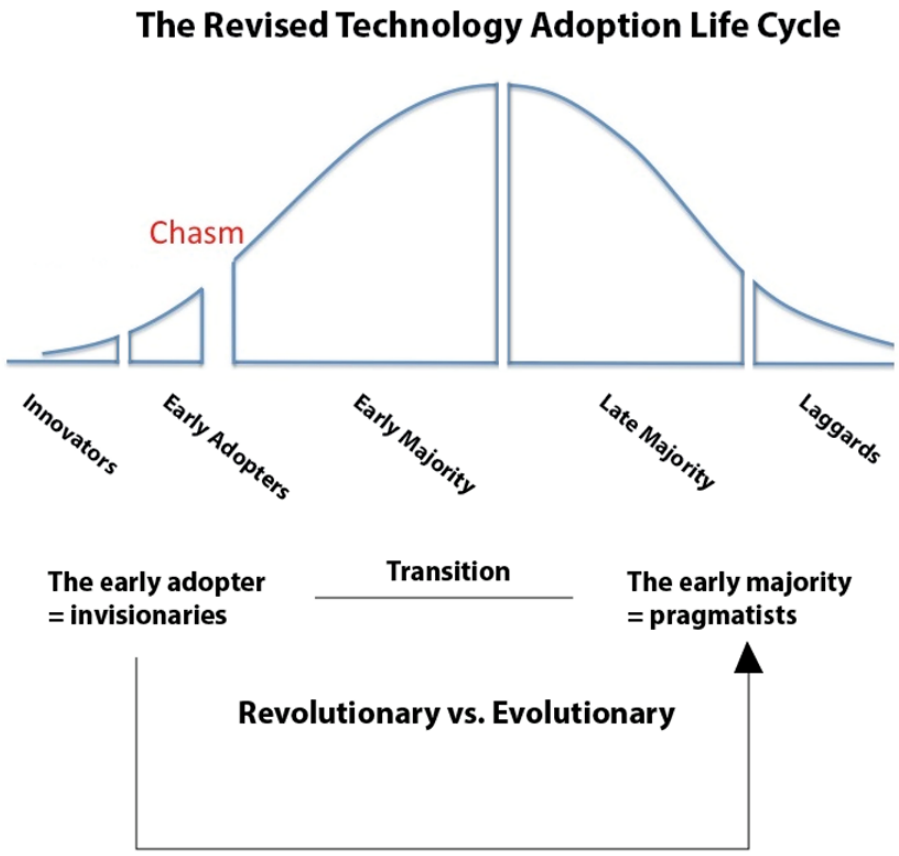


Figure 1 The revised Technology Adoption Life Cycle （Moore 2002）

1.3 Potential Compelling User Case

According to a study of 3000 adults by a United Kingdom-based insurance company, we spend a total of 3,680 hours (153 days) searching for our consumables with an incredible 3,285 items are misplaced every 12 months or just under 200,000 items over the course of 60.5 adult years (Daily Mail, 2012). Being

organized and able to keep all of your consumables orderly is very time-consuming, and the thought of being organized causes extreme stress. Like most people, I am not an ultra-organized person who loves to check things off of a list and remember where every single item is— stratifying all of my clothes by colour, style, and season, for example. As a Millennial, despite my 34 years, as I age, I have started forgetting where my parking space is in big shopping malls, and more forgetful "senior moments" happen daily in my life. Ambient, smart technology with the power to assist me with household and time organization makes a compelling case for people like me and could benefit millions of homeowners in the future.

1.4 Motivation

Personally, I am a huge fan of IKEA, buying almost everything related to my home furnishing and organizational needs there since I have lived as an independent adult. IKEA, for me, is a place where I can make a house my home— affordable prices, workable functionality, attractive design, and a sense of achievement after I assemble everything easily on my own—create a unique, livable environment even in a rental apartment. After I had married, my husband and I continued shopping at IKEA, often once a week, since it is the only place where we both love shopping. As a company so proficient as bringing contemporary, simple design to regular people, why does IKEA not move into

smart home technology and products to help consumers upgrade their homes? IKEA's concept of the future kitchen by using projection mapping is too far away and seems unattractive to current consumers like me. What if IKEA moves forward to become a leader in supplying accessible digital home technology by enhancing their seemingly ordinary furniture?

Another motivation beyond my consumer preference for IKEA is from my professional experience. I have worked as a digital marketing expert for my entire career before coming to Digital Futures at OCAD University. My professional work probed the best strategies to promote unique sales points of a product with smaller advertising budgets. It was selling the products and making the companies' profit that took primary importance, not the usability of these products from a customer, or user's perspective. What kind of technology is the best way to solve our day-to-day challenges? How does the aesthetic experience affect the result of a sale? Digital Futures has allowed me to explore business practice combined with digital technology, research, art, and design; advancing my career by shifting my out-of-date mindset from marketing-oriented to human-centered-design-orientation.

Overall, this major research project and thesis explores the potential of a DIY "enchantment" to household objects to see whether it can help average Millennials like me organize their consumables. This study is not only a research project but also an opportunity to reconsider the design of Internet of Things

(IOT)-related consumable products such as clothing, groceries, and home furnishings from a design thinking point of view. Historically, technology has a tremendous impact on product development. Along with the democratization of technology, citizens are not just consumers but prosumers. They are involved at the earlier stage of the product design and shifted the traditional manufacturing in many ways. However, this maker movement will not change the foundation of the capital hierarchy, according to the inventor of Lilypad, Leah Buechley, who said the majority of makers are "white, rich, guys (2014)". Technology is still not affordable, accessible, or democratic enough for the mass population as we expected in the maker movement. In the context of this project and thesis, such barriers to access suggest that smart home technology is not yet ready (or democratic enough) for mass adoption and adaptation.

As a digital experience strategist and designer, I would like to utilize this research project to validate the hypothesis: Will taking a piece of democratically designed IKEA furniture and applying human-centered design and smart digital technology through a simple DIY approach solve our current home organizing challenges and make accessible the future smart home experience? In other words, I want to validate whether it is achievable to create a "'IKEA' in information and technology sectors, especially regarding the smart home sector, which aims to design for everyone not the few (IKEA 2003)."

The framework of this paper is as follows: Chapter 2 outlines the theoretical background of the approach with a related literature review. After a short description of the research questions, Chapter 3 describes the research process in detail, including the methodology, participant selection, as well as the protocol, materials, and procedure. Chapter 4 describes an experimental prototype development in detail following the framework of Human-centered Design. Chapter 5 concludes this thesis with a discussion of the approach and an outlook on future works.

CHAPTER 2 - LITERATURE REVIEW

This chapter investigated the current academic findings around the home organization, and the potential trouble raised by the overwhelming amount and disorganization of home consumables. Furthermore, the chapter contains a review of the digital formula towards home organizing. The chapter concludes by addressing the research questions through the lens of the theoretical framework.

2.1 The Number of Home Consumables

The term "consumables" refers to the goods used by individuals and businesses that must regularly be replaced because they wear out or are used up (Wikipedia). Consumables can be clothing, groceries, and such daily-used items. Even though consumables are expendable, the statistical data about our home is staggering. Professional organizer Regina Lank said that the average three-bedroom home has 300,000 items (MacVean, 2014). According to the Bureau of Labour Statistics, the average American family spends $1,700 on clothes annually (2016). In 1930, the average American woman owned only nine outfits(Long,2015). Today, they own 30 outfits -- one for every day of the month (MacVean 2014). The Daily Mail reported that women in the United Kingdom buy half of their body weight in clothes each year, and the average woman in England has 22 unworn items in her closet (Mailonline, 2012). One fascinating

study of middle-class American families found that three in four garages are so packed with consumables that there is no room for a vehicle(Johnson,2015).

This is so commonplace that a new occupation, the professional organizer, has blossomed due to people's need to organize their homes. The National Association of Professional Organizers reports that organizing consultants, companies, and products associated with them, such as The Container Store, has grown into a $1 billion industry (Johnson,2015).

There is no judgment, right or wrong, to having a tremendous amount of consumables. This, however, creates the problem of owning too many things and making our homes increasingly messy and disorganized, which is troubling to daily life. On top of all of our consumables—our disorganization—we become forgetful trying to keep up with all of them. For Millennials, ordinary forgetfulness is likely not a sign of a more serious medical condition like Alzheimer's Disease or Dementia, however, "forgetfulness is quite common," says Sebastian Markett, a researcher in psychology neuroscience at the University of Bonn in Germany (Mike, 2014). Due to the overwhelming volume of stuff and our increasing "forgetfulness," daily searching became time-consuming and familiar. The research found we misplace up to nine things every day, adding up to 198,743 misplaced items in our lifetime. Our phones, keys, sunglasses, and paperwork top the list (The Daily Mail, 2012). The study also found that four out of ten people often argue with their partners and spouses about these lost items.

Our disorganized homes also might cause a rise in symptoms of depression. Family and occupational therapist Patricia Gutentag notes that not having an organized home creates stress and "often leads to forgetfulness, depression, and poor judgment…We find higher rates of ADHD (Attention Deficit Hyperactivity Disorder) diagnoses in young adults…a population that has grown up multitasking using technology, often compounded by a lack of sleep, all of which results in high levels of forgetfulness (Emling, 2013)." A 2013 Trending Machine poll found that Millennials are more likely than those over the age of 55 to forget what day it is (15% versus 7%) and where they last put their keys (14% versus 8%)(Gregoire,2013). Millennials might even forget to take a shower (6%) more frequently than seniors(Gregoire,2013). Rising stress levels, which may be related to their constant connectivity could be a factor as well. Millennials' stress of having disorganized homes is compounded by their busy, connected lives (Thaler 2016). More seriously, people feel a lack of control in their lives, particularly when their home is in disarray. People need to organize.

A 2010 survey concluded that 80 % of people agreed that being organized improved their work performance and may lead to feeling more in control as well as having the more mental energy (McGinn, 2016). Heaven for ultra-organizers are shops such as The Container Store, IKEA, Home Depot, and Lowes, places where they can find the home organization furnishings and tools to help deal with all of their consumables.

2.2 Digital Solution for Home Organizing

- *Organizing Thing versus Organizing Information*

> "What is difficult to identify is difficult to describe and therefore difficult to organize (Svenonius 2000, p. 13)."

In the book about the discipline of organizing, Professor Robert Glushko states that "organizing things" is contrasted with "organizing information" (2013). Glushko et al. (2013) claimed that organizing things and organizing information sometimes does not differ when information is represented in a tangible way. More specifically, people organize physical things depending on the visual information such as shape, size, the material of manufacture, or other visible properties. Things are forms of tangible information. In the context of home, once people organize the visual information of their consumables, they then have a chance to organize and manage them. One challenge here is how to identify our consumables, make them identifiable, and give them digital capacity, enchanting them, so that the consumables can "talk."

- *Previous Digital Approach for Home Searching and Organizing*

To deal with searching for the objects we use and rely on daily at our homes, engineers from Japan invented a smart robot called TansuBot which helped people position their objects in their homes by reviewing pictures of the

contents of home stored on a smartphone. The TansuBot had a movable camera and mechanisms to push a cabinet drawer forward (Figure 2) as well as LED lights that blink when people are searching for their things. Although the researchers considered customers' ease-of-use and cost features by using a wooden material to create the prototype, the complexity of TansuBot as shown in the framework picture (Figure 2) makes it almost impossible for end-users to adopt the TansuBot shortly, not to mention the related cost of purchase. However, experimenting with TansuBot proved that photographs displaying contents on a smart device and showing candidate drawers to investigate had positive effects on reduction of searching time and mental burden.

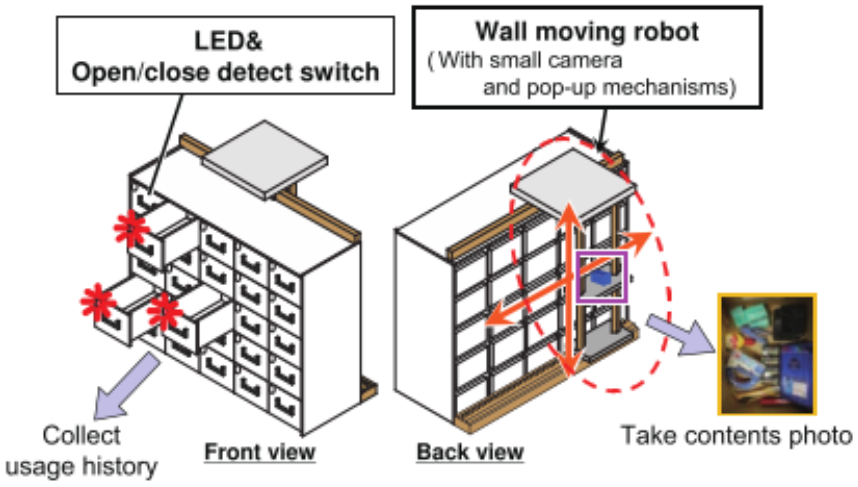


Figure 2 TansuBot Prototype(Fukui, et al., 2013)

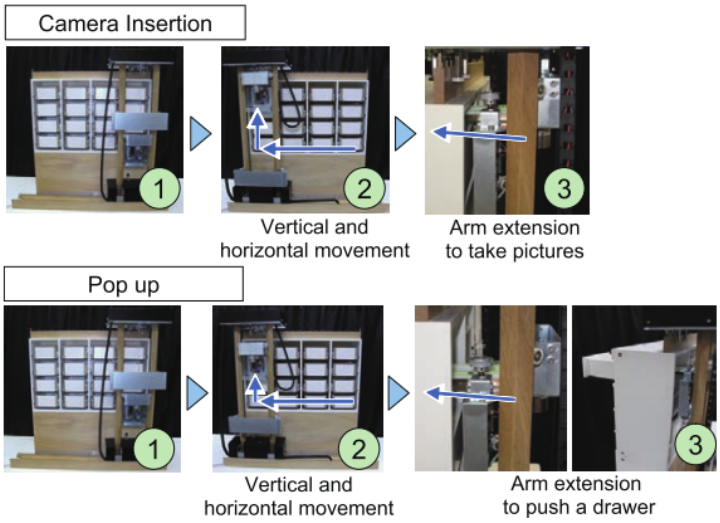
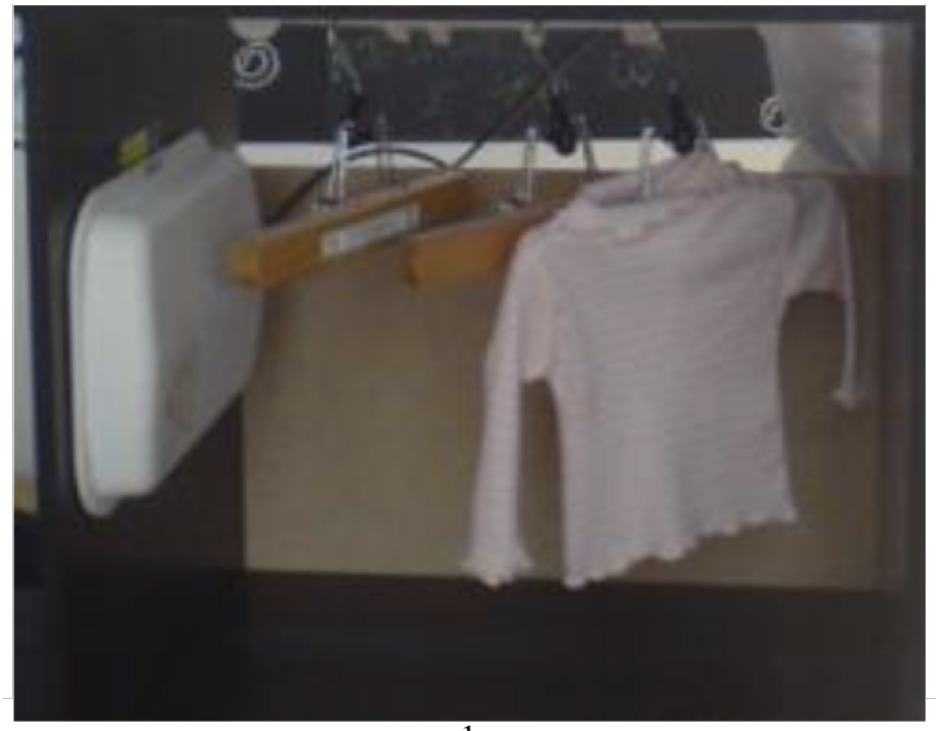


Figure 3 Sequential Snapshots of Robot Motions (Fukui, et al., 2013)

Clothing items are another overwhelming fact at home, and choosing the right garment for the occasion can be frustrating and time-consuming especially in today's world where people are always in a hurry most of the time (Goh, et al., 2011). Researchers also noticed that people tend to stick with limited items, usually one or two styles and buying new clothes that are very similar to the ones they already have (Goh, et al., 2011). This usually results in the waste of time and money. The University Teknologi PETRONAS have experimented with a digital wardrobe (Goh, et al., 2011). The University team iterated the smart closet, and Chantal Mora's Digital Wardrobe prototype sewn with a wearable Radio-frequency identification (RFID) tag into a collar or sleeve and installed a RFID reader on the hanger. This system could store data such as the colour, fabric, and cleaning instructions for a particular garment as well as what sort of occasion the

item could be worn to. After uploading the data, the smart closet system recommends outfits based on the colour, style, and mood of the wearer based on an algorithm. This research paper by Goh et al. does not contain any user testing data or presents how their algorithm worked (2011). However, applying FRID technology into the fashion industry to assist with managing day-to-day clothing choices and organization provides an alternative and cheaper solution to organize our homes. After reviewing these current organizing solutions, how can these experimental innovations be effectively tested and incorporated into our day-to-day use?



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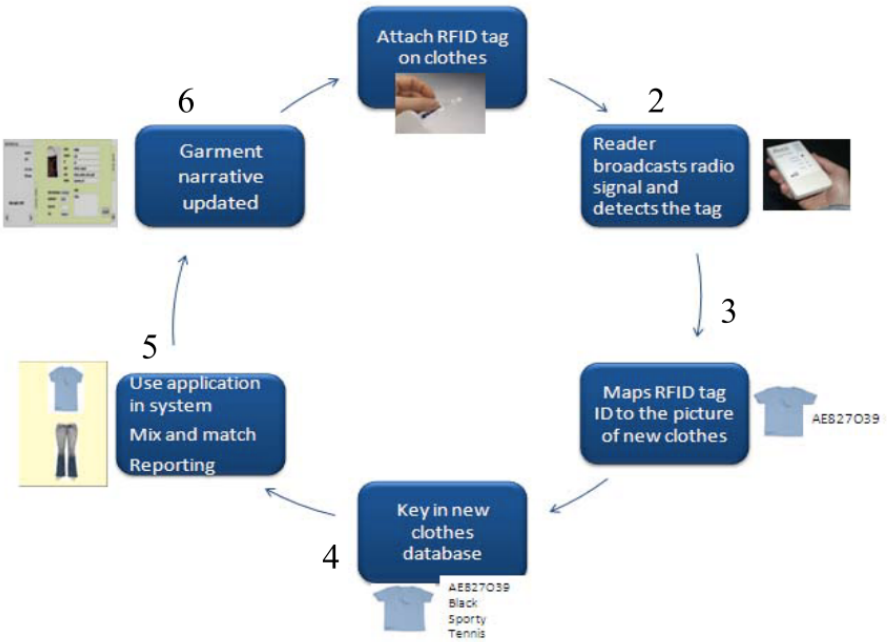


Figure 4 Smart Wardrobe Prototype and System (Goh, et al., 2011)

2.3 Theoretical Framework and Field Study

- *Democratizing Design*

Democracy is a term with multiple, at times conflicting, meanings and methods. In modern usage, “democratic” is an adjective to describe a decision-making process sometimes referred to as the "rule for the majority (Dahl, R. A., 1957)” in political policy. It also describes the public accessibility to technology, knowledge, and products (Hippel 2005). From Jason Lian’s point of view, “the democratization of design" is an attitude toward product development, which involves well-designed on aesthetics, function, and format as well as low price as that the majority of people will be able to afford (2012).

Influenced by Scandinavian design, which is a term that represents a design movement characterized by simplicity, minimalism, and functionality (Digerfeldt-Månsson et al., 2005). Invar Kamprad established IKEA in 1945. After several years in operation, he realized that knockdown, pre-assembled furniture could lead to significant cost-savings to transportation and assembly, the most expensive parts of his business, passing these tasks on to customers. Based on the systematic design approach towards flat pack and self-assembly, IKEA initiated a democratic design framework to guide “the design for the many, not few (IKEA 2003).” Their simple but pretty form, high function, great quality, and accessible and affordable low prices promise the average consumer an easy to create “beautiful home (Coline,2015).” However, IKEA elaborated in its

anniversary catalogue, “producing beautiful furniture is not difficult. The difficulty lies in producing it at a price which most people can afford to pay” (Zhuang,2015). By encouraging self-assembly by the consumer, IKEA maintains not only the lower manufacturing cost but also a higher level of self-satisfaction in customers’ ability to build furniture on their own (Norton, Mochon, and Ariely 2011). IKEA is not only a brand name but also a lifestyle (Rosner and Bean 2009). Moreover, IKEA has tapped into their customers’ individual creativity by offering a variety of designs that can be mixed and matched to fit one’s needs and tastes through “IKEA hacker” practice (Zhuang,2014). Hackers use IKEA’s affordable furniture as raw materials to design their very own creations. Rosner and Bean’s (2009) research of the IKEA hacker community discovered how people bundle the on-line world of bits and the material world of everyday stuff. In short, for them, “furniture can be hacked,” and the environment can be “programmed” with the help of online instruction (Rosner and Bean 2011). IKEA embodies the democratic spirit not only by selling affordable, buildable furniture in a package, but also opening new options to the user who can facilitate creativity through hacking these natural IKEA products (Zhuang,2014). Could IKEA and its customer-hackers go a step further and facilitate incorporating technology into IKEA products to create simple, smart home products? Could these ideas and hacks bring a democratization and accessibility to smart home technology that

might help homeowners better organize all their consumables not only their homes but their busy lives?

Figure 5 IKEA's Democratic Design Framework 2015

- *DIY hacking for HCI*

Wolf and McQuitty defined do-it-yourself as behaviors where "individuals engage raw and semi-raw materials and parts to produce, transform, or reconstruct material possessions, including those drawn from the natural environment (e.g. landscaping) (2011)." The term of Do-it-yourself can be traced back to 1912, which has been associated with Arts and Crafts Movement in the U.S (Mota,2011). It evolved from cost saving home improvement activities of the 1940s and 1950s into a creative act of rebellion against mass production, consumerism, planned obsolescence and waste (Mota,2011). Along with the emergence of a broad range of democratized technology practice, the value of "making is better than buying" has echoed in the shift. A shift where the dominant paradigm of user-as-consumer gives way to alternative framings of the user as a

creative appropriator, hacker, tinkerer, artist, and even co-designer or co-engineer (Ames et al., 2014). Also with the shifting of the notion of the user from consumer to appropriator, or prosumer, these practices shift us from considering technology use as primarily a productive or useful experience to an aesthetic experience (Roedl et al., 2015). A subset of the DIY community is the hacker or maker who modifies hardware, software, or any objects in some way to entirely customize an object or program to be more personalized and customized to meet their needs. Hacker or Maker behavior has been of increasing interest to human-computer interaction researchers. A distinction can be made between conventional "hacker" and "IKEA's hacker" whereby they have different realm and different levels of technology literacy. The IKEA hacker is more focused on the material, but the majority of hackers and makers came from the digital computer realm. Usually, they are highly skilled computer expert capable of breaking into computer systems and networks using bugs and exploits (Schiller, 2011). The current generation of maker and hacker is often possessed of sufficient free time and access to resources to engage in relatively risk-free making (Tanenbaum et al.,2013). In other words, the threshold is very high and inaccessible for the mass population. Even with the digital instruction, hacking, making and copying is harder for the non-experts and has seen shown to consume a lot of time in troubleshooting (Mellis & Buechley, 2014). However, the popularity of IKEA's material hacker practice had proved that the standardized resources can be an

opportunity to create personal solutions that can be shared and reproduced within a community, originating either from necessity or pleasure (Roedl et al., 2015; Rosner & Bean, 2009). It is possible that a standard kit is a less expensive solution to support hacking and making because it's unassembled, replaceable and reconfigurable(Mota,2011). In the context of the home environment, is it possible to create a standard kit to lower the technology threshold and cost of hacking?

- *The Enchanted Objects: The Ordinary Made Extraordinary*

Massachusetts' Institute of Technology Professor Doctor David Rose (2004) argued that the secret to creating technology that is attuned to their human owners is to "enchant" our tools and objects, to help them anticipate the needs of those who use them. "Enchanted objects" refer to ordinary objects that continue to serve their purpose, but they also have something extraordinary alongside their typical functionality. To add these extraordinary and new capabilities is called "enchantment (Rose 2014)." He developed a framework called the Ladder of Enchantment to guide enchanted object design. The first step is to establish the ubiquitous connectivity by adding sensing or sensor capabilities within the cloud. By doing so, our everyday objects could extend their capabilities and sense and signal information, process and store information, and deliver new services. Once connected, the product or the design can be personalized by leveraging and feeding information. "Sociality" is nature of human beings and "connecting with others" might have multiple meanings for people. Sharing information with

people on social media (Twitter, Facebook, and WeChat, for example) is part of our daily common activities. When our objects become enchanted, sociality will be not exclusive to humans, our things or consumables can interact with us and with each other, to create also person and person, but also thing to thing, relationships which are more meaningful and valued.

> "Climbing the ladder of enchantment bestows more personality, more product differentiation and the ability to charge a premium with each step (Rose 2014)."

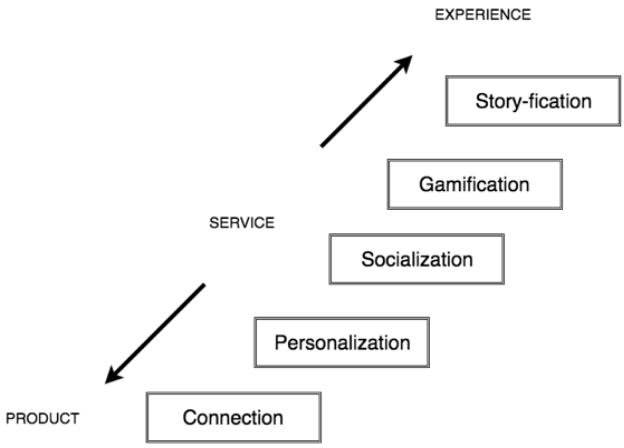


Figure 6 Ladder of Enchantment (Rose 2004)

- *Sweet Spot for home organizing*

By using a Venn diagram (Figure 7) to illustrate the intersection of the democratic design framework, the ladder of enchantment (Figure 6), and DIY hacking practice, the "sweet spot" for innovation becomes achievable. The

combination of democratizing design and do-it-yourself practice allows people to remix and mashup home furnishings, using arts and crafts to fulfill their personal need for creativity, aesthetic preference, and home organizing. The majority of current IKEA hacking activities are as simple as home decoration. Smart gadgets, such as Tile-Mate and Trakr, are the result of hacking and enchanting to solve daily searching. The problem is the price is still too high for mass-adaptation. Florence Ion, a Greenbot writer, questioned that not many people are willing to pay $25 a year for a device that just locates your keys (2015). Not to mention, there are millions of smart home objects and identifying what you and your family might need comes with many considerations and are not simple decisions. Examples found on hacking tutorial websites like instructables.com and the Arduino community is the aggregation of hacking and enchantment ideas. However, as Mellis and Buechley argued that the DIY cellular phone, an investigation between possibility and limited high-tech DIY, that "there is a big gap between having access to the technology and building devices for use in one's daily life…Those cases require high levels of programming skills, which are not available to the mass user" (2014).

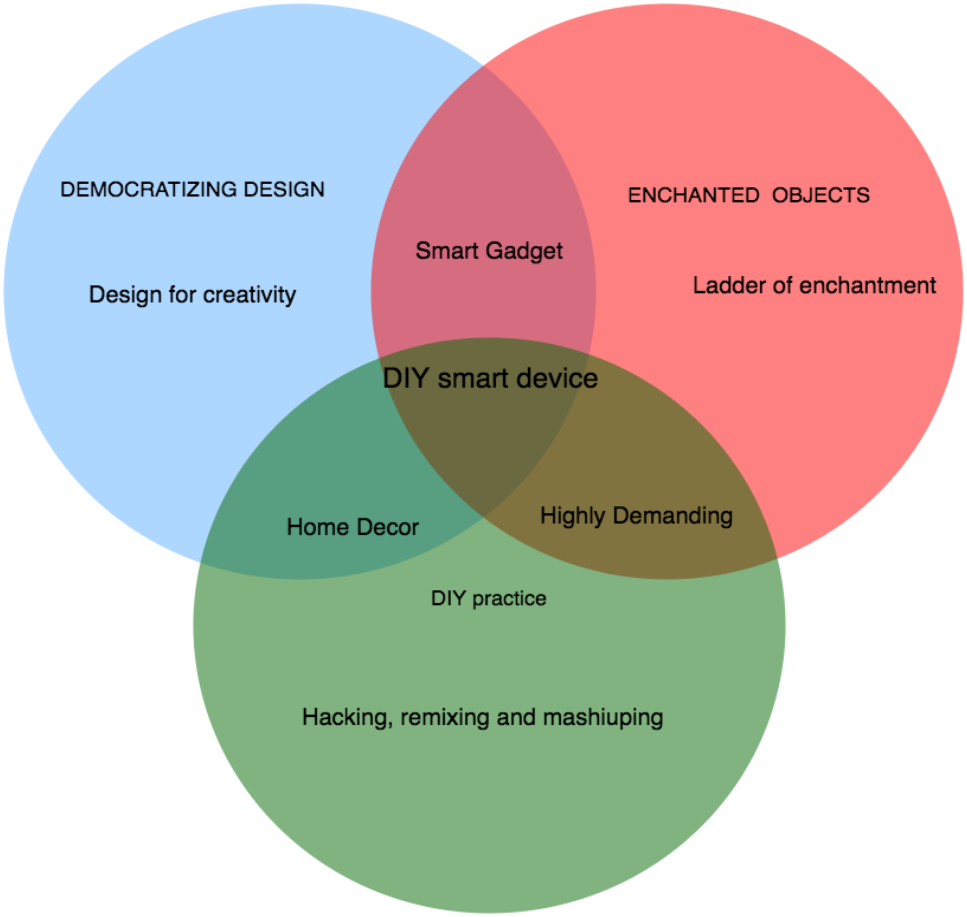


Figure 7 Sweet Spot for Innovation

This thesis takes the viewpoint that it is not economical or accessible for many of us to organize our homes by purchasing new smart home furnishings and products. Personally, I believe the goal of the Internet of Things (IOT) is in "designing innovative Internet-connected experiences and augmenting existing objects' capabilities with Internet-related features (Muguria et al.,2009). By bringing the new connection to dummy things such as container furnishings, new services can be created and be used by the devices and humans. Moreover, if the

enchantment could be produced through DIY activities, based on the literature above, it might bring an affordable, pleasure and creatively expressive solution to motivate the passive consumer to attempt organizing at home (Tanenbaum et al.,2013)."

The idea of applying the combination of democratized technology and DIY practice in smart home-related product development is not radical new as several researchers have stepped into this field. Woo and Lim's research examines user experience in do-it-yourself-style smart homes (2015). They conducted three-week in situ observational study involving eight households to examine whether DIY smart home products are a potential solution to the current challenge related to home automation products, such as inflexible user controls and high costs of purchase and installation. The advantage of the DIY-style smart home includes customization to fit into changing routines; low cost without expert installation, and replacing old equipment at home (compared to completed systematic product). Maintaining individual control and increasing usability was also an advantage, considerations often missed in smart home products. The drawback is high-entry-threshold required, as their paper claimed, at least one family member was familiar with the DIY electronic practice. Related to this, the family members with a little computer literacy lose more control of the smart home devices because these objects are purchased and set-up by another, more technologically literate family member. The design implementation also reveals

that the future DIY-style smart home products should be able to assist in forming better, more structured daily routines. Moreover, pure aesthetics play a significant role in integrating smart home technology into homes as users worry about damaging their home's original infrastructure and decor. To mitigate this, DIY smart home products should consider easily attachable and detachable features. Lastly, the easy-to-use operation interface is crucial to users since not all the users in the same family have a similar knowledge level or comfort in programming smart home devices.

Figure 8 Study toolkits: Ninjablocks (Woo et al., 2015)

University of Waterloo Professor Hwang et al. investigated how DIY smart home technology might assist with our aging society, particular seniors with Dementia (2013). The prototype was comprised of three parts: the interface for end-users to express contextual knowledge, needs, and preferences in a natural way. The computer encodes users spoken, natural language into the system with

an intelligent sensing and control system, which are hidden from end users. With simple installation, the caregiver can set up a customized smart home. The system serves as a run-time processor for assisting with specific tasks and provides a dynamically evolving variant, customizable in real-time by end-users and product developers. Additionally, this DIY smart home is not a one-time set-up, it allows end-users to slowly design and add fresh functions as they discover new or changing needs. The advantage for this product is high customization and user-friendless. However, its major function is to remind or guide the person with dementia to accomplish a certain task. The complexity of this project is low, and the set-up and usability are very straightforward. Another advantage is that the encoding function relies on the connection users have with developers, customer service representatives, who can provide real-time support so that users can use their natural language without coding. It is a simple task DIY smart home system that does not yet handle multiple tasks at the same time. Even so, this project reveals the potential use of DIY smart home products that can solve problems of misplacing our necessary items and decrease our forgetfulness in everyday life.

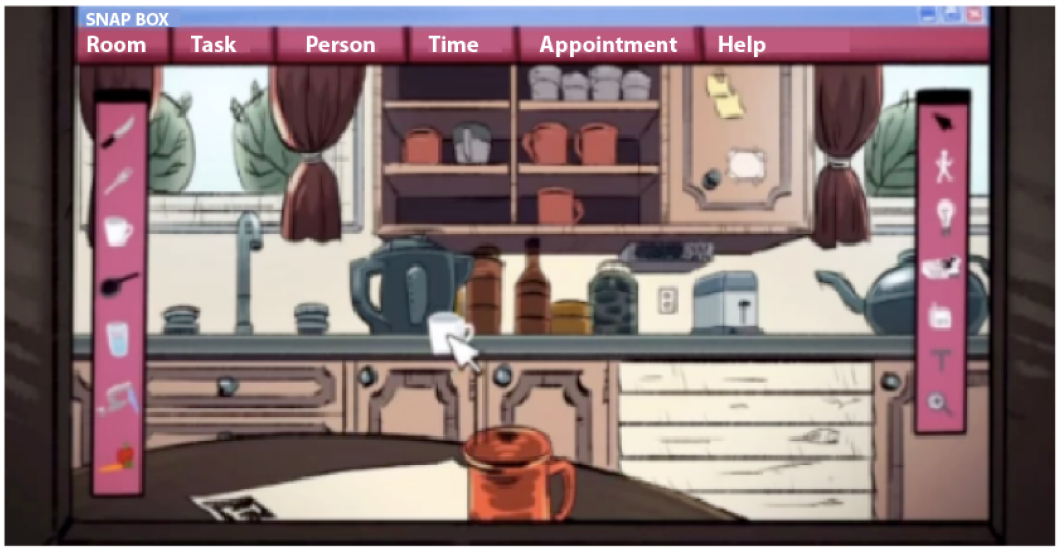


Figure 9 Conceptual User Interface Mock-Up For A Sensing And Control System (Hang and Hey, 2012)

The projects discussed above pointed out some of the implementation measures necessary to designing a DIY-style smart home, however, none of them concentrate on handling specific tasks such as organizing consumables. This is the problem which I aim to solve.

- *Research questions*

Hence, in the context of home, under the theoretical framework of democratic design, enchanted object and DIY for HCI, I want to propose a DIY enchantment to establish new connectivity between furniture and consumables, such as clothing, daily-use items, and food, to enhance ordinary functionality of furniture as well as endow them with new capabilities to provide personal and social services to organize homes. Through this research, the following research

questions will be addressed:

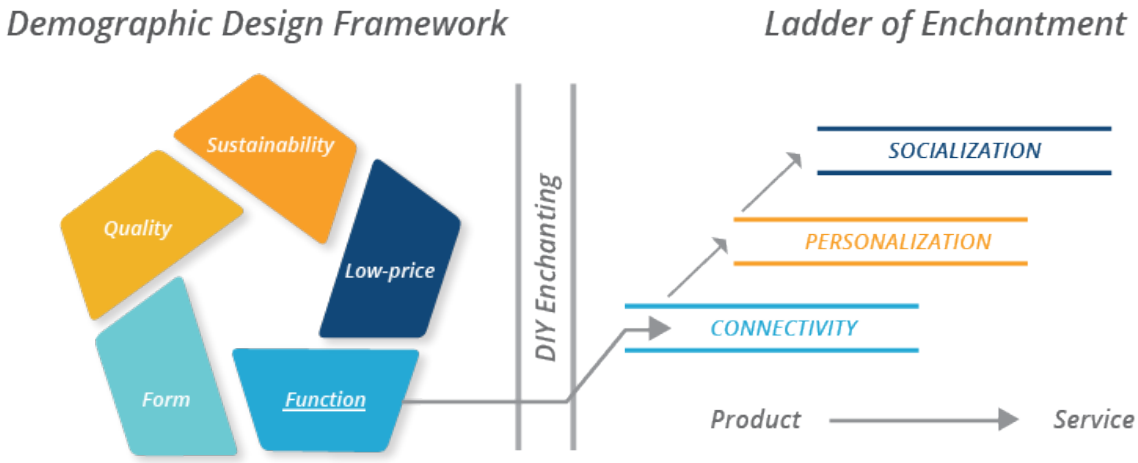


Figure 10 Positioning Research Questions

1. What kind of smart furnishings could be potential solutions for better organizing our home?
2. Through design exploration, what kind of DIY enchantment might be possible for people with low hacking literacy or ability to deal with home organizing?
3. How might potential consumers respond to a toolkit that will assist them in simplifying new smart home possibilities?

CHAPTER 3 - RESEARCH APPROACH

3.1 Chapter Overview

The essential aim of my research was to investigate what kind of DIY enchantment is accessible and affordable in helping people to organize their homes better to deal with messiness in their daily lives—specifically, challenges related to organizing consumables.

Human-centered design will be the core creative approach and needs to be concentrated on to provide a user-friendly experience. Hence, discovering what kind of research methodologies and processes could involve humans in the front-end of the design and prototyping adequately and continuously is crucial. Not to mention the different target groups that hold various perspectives and hacking abilities. This chapter will illustrate the research methodology in detail. In the following subsections, this body of the investigation provides a narrative description of the research design around methodology, participants, procedure, materials, and protocol.

3.2 Research Methodology

Recent research into human-computer interaction suggests that for complex systems such as networked objects in the Internet of Things (IOT), researchers need to have a complete understanding of the dynamics of human-machine interaction (Sundmaeker, et al., 2010). Extracting information from

applications which are linked, with different complexities, and presenting it in a useful way, requires consideration from a human standpoint as well (Ganesh, S., & Malhotra, R. 2015).

Human-centered design is an approach for developing interactive systems that aim to make systems usable and useful by concentrating on the users and their demands and requirements, as well as by applying knowledge and technologies from the field of ergonomics related to usability (ISO 9241-210:2010). As mentioned at the beginning of this thesis report, the barriers for creating smart devices that would help households organize is not about cutting edge technology but rather affordability and a positive user experience which must be integrated into the design of any smart home devices if there is to be significant mass adoption. Considering that Near-field Communication (NFC) technology has existed for decades and available at an affordable cost, the rest of the research will emphasize how to create a compelling experience by applying the human-centered design. To make sense of what kind of new enchantment is needed to help us organize, the whole process will start with acknowledging the people I am designing for and end with a new toolkit solution suitable for their needs designed with a deep empathy for participants using it. Considering this project will use IKEA products as a basis for enchantment, the target audience will be Millennials, again, who are the demographic cohort born between the late 1970s to the mid-1990s (possibly into the early 2000s), who will be the key

collaborators. For this study, participants may or may not have children. The rationale for choosing this demographic comes from (1) IKEA's aim to target people from all ages, sexes, and geographic location (IKEA, 2003), however, Millennials are the key target audience age group because they are a driving force for sales due to their large population size and their median age group now established in their careers, beginning to marry, have children, and buying homes (Hamber, 2015); (2) another factor is Millennials' lifelong familiarity with digital technology but also with the concept of smart homes, hacking, and modification; (3) Millennials are also seeing an increase in forgetfulness and distraction as discussed in the literature review portion of this paper.

3.3 Project Research Design

- *Research process overview*

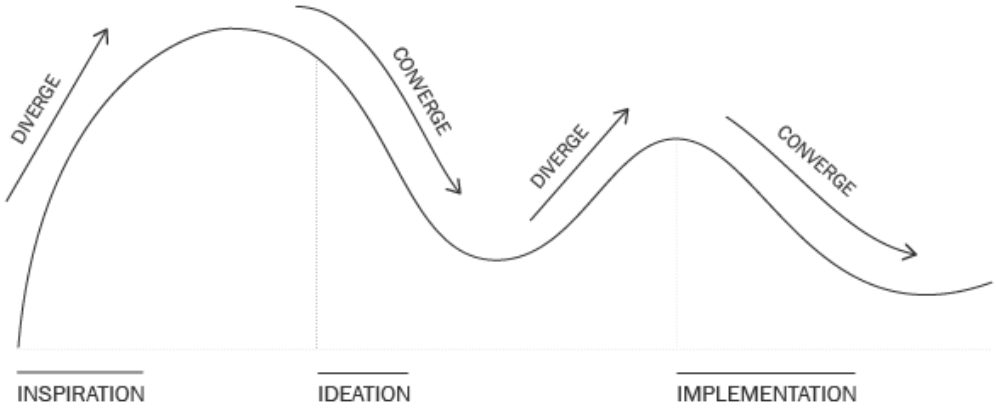


Figure 11 Human- Centered Design Process from IDEO (2009)

According to IDEO, the Human-centered design approach consists of three phases: inspiration, ideation, and implementation (IDEO, 2009). The design of DIY enchantment, a hacking toolkit, will also include these three phases of design. (1) The inspiration phase includes exploring and identifying where and what home furnishings within the home context might be enchanted. (2) In the ideation phase, through the design workshop, it explored and identified design considerations and requirements for average Millennials to hack home furnishing through the DIY approach that will work best for them. (3) The implementation phase in which a DIY enchantment, called SMARTKIT will be prototyped and iterated while continuously involving potential target audiences; at the end, the final version of SMARTKIT prototype will be tested, and user responses will be gathered to echo the research questions above. The overall process is illustrated in Figure 12.

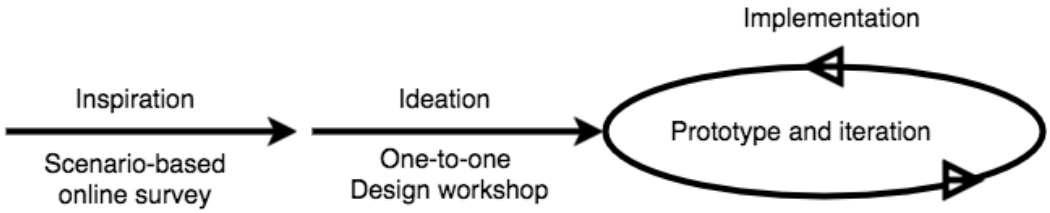


Figure 12 Thesis Research Process Design

- *Methods*

In different research phases, various methods were applied to fit best the needs of gathering information, analyzing unmet needs, and gaining direct feedback. [1] Questionnaires were used at the beginning of the research project to make sense on what kind of messiness and disorganization most Millennials suffer with, and what kind of possible creation would make sense to use in their homes to alleviate the disorganization. [2] A design workshop, executed in Phase 2 of the project, allowed me to gain first-hand input from stakeholders through activity-based research. Considering materials and space constraints, the study conducted in the design workshop was a one-to-one communication with informational interviews at the end of the workshop. [3] User testing was an ongoing process since Phase 3 when the prototype was developed. The dynamic and real-time interaction provided insightful findings allowing spiral iterations of the prototype. [4] The project ended with the formal user testing where participants went through the steps of given tasks using the final version of SMARTKIT.

- *Protocol*

The research participants ranged from 20 to 35 years of age, and this was consistent for all of the research phases. Participants were recruited by email, social media, or other channels through the researcher's personal network. Considering that the researcher sought a general response, there was no specific

demographic requirement regarding cultural background, gender, and literacy level. Participants who took part in the ideation and implementation phases were required to follow a designed procedure to give an informative response. Before the individual research session, participants were fully informed about the research topic, experimental procedures, and provided their written consent. Participants took part in the user testing workshop held at the Ontario College of Art and Design University's Digital Futures Studio at 205 Richmond Street West in Toronto, Ontario, Canada. The research project was approved by OCAD U's Research Ethics Board.

- *Materials*

1. Toolkits

Arduino and Littlebits toolkit were used. I selected Arduino Uno based on its popularity among maker and hacker communities and their ease-of-use functionality for beginners. Littlebits is another similar electronic block invented by Ayah Bdeir in MIT and gained high reviews from their current customers such as educators, students, and hobbyists. What I found most appealing about Littlebits was the company's official production of instruction videos to show how to use this toolkit was crucial for me as user-friendliness is a vital aspect to the success of toolkits. Comparing Littlebits with the Arduino community, the Arduino supporters (hackers) follow a more informal structure and appear to be

more self-motivated and hold a higher computer and technology literacy level. The Littlebits community is closer to the general population rather than hobbyists or professional users.

2. Task instructions

Participants were given two video assembly instructions and one paper instruction sheet. The videos, Ardino's Hello World, available on Youtube and created by Curtis Ireland (2016); the other Littlebits video, entitled Smart Refrigerator by Littlebits. As an investigator, using the original instructions created by and from the maker community could provide more informative insight to probe further the gap between having access to the technology and actually building and hacking devices for use in one's daily life.

3. Questionnaire

On the online questionnaire, participants were asked to self-evaluate their own experience and capabilities in assembling and installing IKEA furniture. They also required to vote for the messy cases they experienced most and what kind potential solutions were attractive to them. The questionnaire was created with Google Forms and shared within my personal network through social media such as LinkedIn, Facebook, as well as my personal email group.

4. Interview Guidelines

Once the user-testing component of the project was completed, participants were asked to participate in short, 10 minute informational interviews.

Five of the questions were open-ended aiming to let people give direct feedback that could be further incorporated without setting a bias.

- *Procedure*

The procedures for participant recruitment and written informed consent followed the Ontario College of Art and Design University's Research Ethics Board guidelines. For the design workshop, participants were taken to the OCAD University Digital Futures' studio space and introduced to and informed about this research project. After their informed consent was given, the participants were asked to complete two hands-on tasks, one called "hello world," and the other called "Smart Refrigerator." Participants were given 40 minutes to complete the tasks. After that, participants viewed a five-minute video introduction of FlipFlic, a smart window blind mechanism, and asked to evaluate the product design and responded to interview questions about FlipFlic. In the user testing portion, participants were given cellular phones and asked to go through all the steps of the mobile interface to test the functionality of data input, tapping the NFC tag, and remaining output within a 30-minute timeframe. This was followed by brief interviews to gather participants' reaction to the user-testing.

CHAPTER 4 – EXPERIMENTAL EXECUTION

4.1 Chapter Overview

> "I invented the term (User Experience Design) because I thought human interface and usability were too narrow. I wanted to cover all aspects of the person's experience with the system including industrial design graphics, the interface, the physical interaction and the manual. Since then the term has spread widely, so much so that it is starting to lose its meaning."
>
> — *Donald Norman (2010*)

To manifest solutions for home organizing by DIY enchantment, SMARTKIT, which contains an enchanted hardware, a tangible interface with a cloud system, and installation instructions will be initiated and developed in this chapter. The following will describe the three phases of this project—inspiration, ideation, and implementation—and give detailed documentation of the development of the prototypes successively.

4.2 Experimentation

4.2.1 Phase One: Inspiration

To understand what kind of mess and disorganization average Millennials suffer from the most in their homes, a quick scenario-based online survey was initiated. 84 participants of Millennial age and younger (20-35 years) responded to this survey. Almost 45% of participants claimed that they forget what the food they have in the fridge is, even after it has expired. Around 34% of people experience many searching for small misplaced items at home; and 20% of these

individuals said they have, “too many clothes in their wardrobe or closet.” To help with home organizing, participants were asked what smart devices or enchanted home furnishings would be most preferred. The top three choices were: a smart drawer which can inform the user of what items are inside; a smart tag which can inform the user of what food has expired; and a smart closet which can indicate to the user which clothes are favorites (worn the most to worn the least).

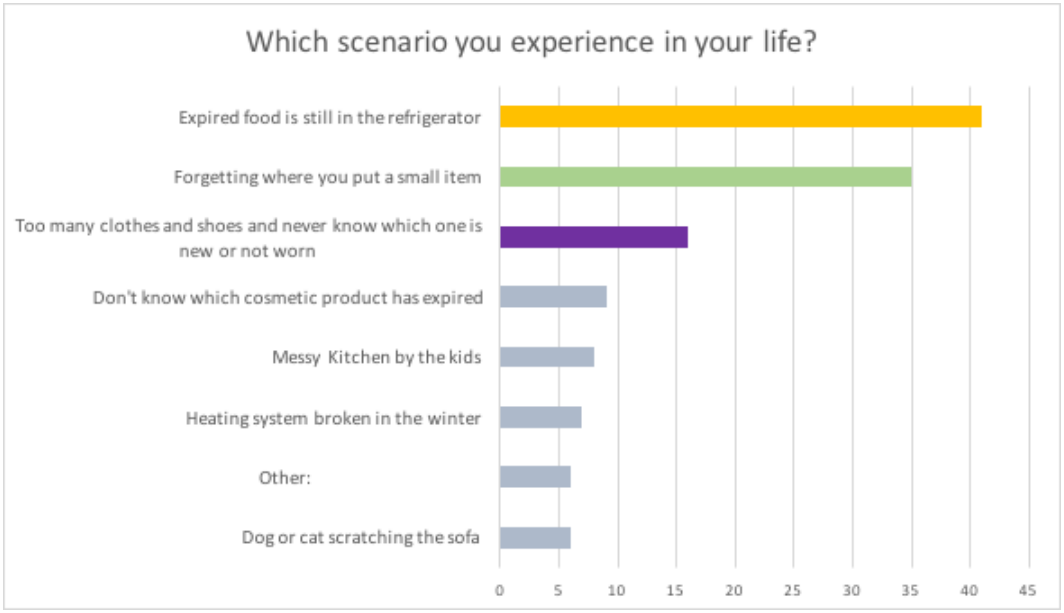


Figure 13 Questionnaire Result 1_ Investigation of mess at home (Unit:%)

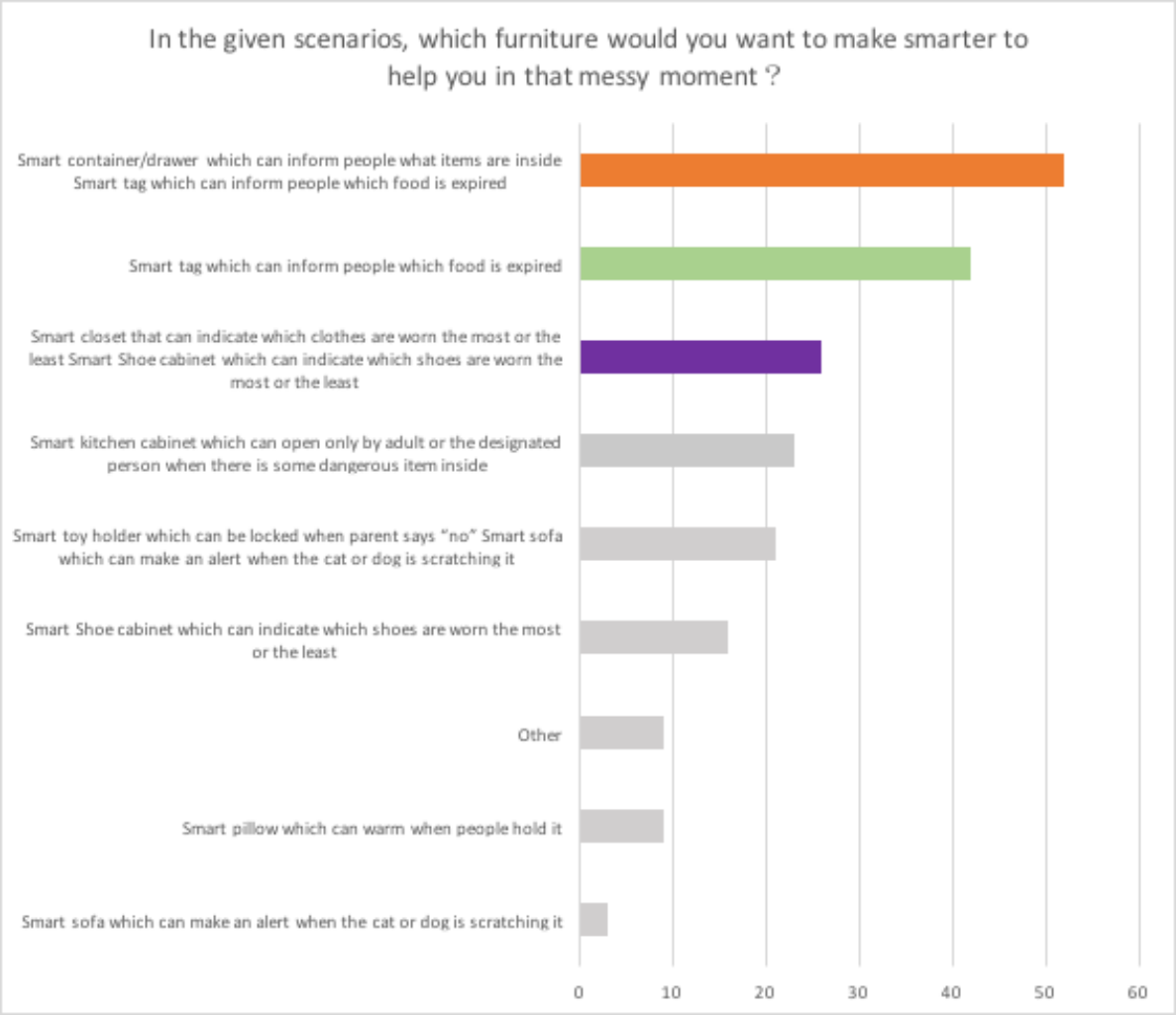


Figure 14 Questionnaire Result 2_ Investigation of potential organizing solutions at home(Unit:%)

4.2.2 Phase Two: Ideation

- *Procedure*

The goal of this phase is to explore the potential design opportunity and solution to hit the pain points of home organizing. In this phase, a one-hour design

workshop was facilitated to observe how participants use current DIY toolkits such as Arduino and Littlebits. Participants used these kits to create smart objects of their own. The objective was to: (1) investigate what the barriers there are for average Millennials to use currently available DIY hacking toolkits; (2) determine which skill levels each of the toolkits could be made more accessible, or democratized, for average Millennials; and (3) indicate what design requirements should be considered for developing a future modular toolkit?

12 participants ranging in age from 20-35 years and different sexes (six males and six females) were recruited from my personal network found via my email contacts. Each was asked to participate in the design workshop which included:

1. Introduction to the workshop (5 minutes)

Two hands-on hacking activities based on and following video instructions (40 minutes)

Arduino, “Hello World” (figure 15)

Littlebits, “Smart Refrigerator” (figure 16)

2. View and respond to FlipFlic smart window blinds video (10 minutes) (figure 17-18)

3. Post-workshop interview (10 minutes)

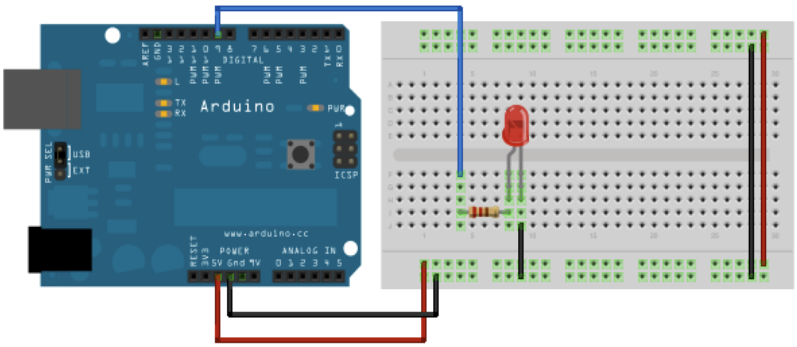


Figure 15 Arduino Electronic Circuit "Hello World"

Figure 16 Littlebits SMARTKIT

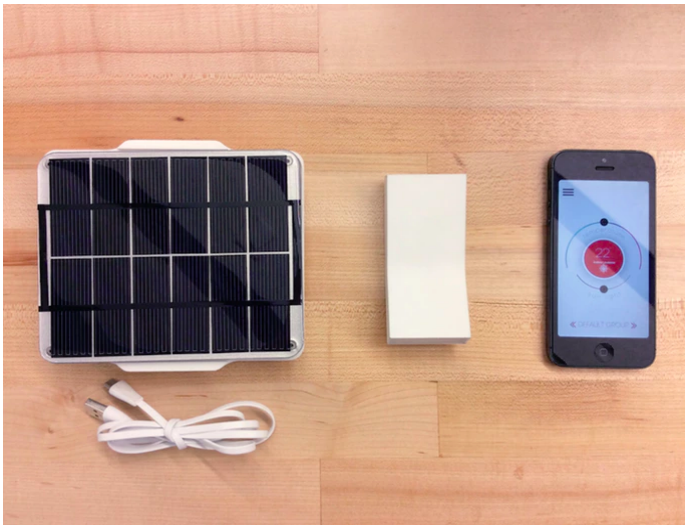


Figure 17 FlipFlic Hardware Parts: Solar Panel, Mechanical Box, and Mobile Interface

Figure 18 FlipFlic Installation

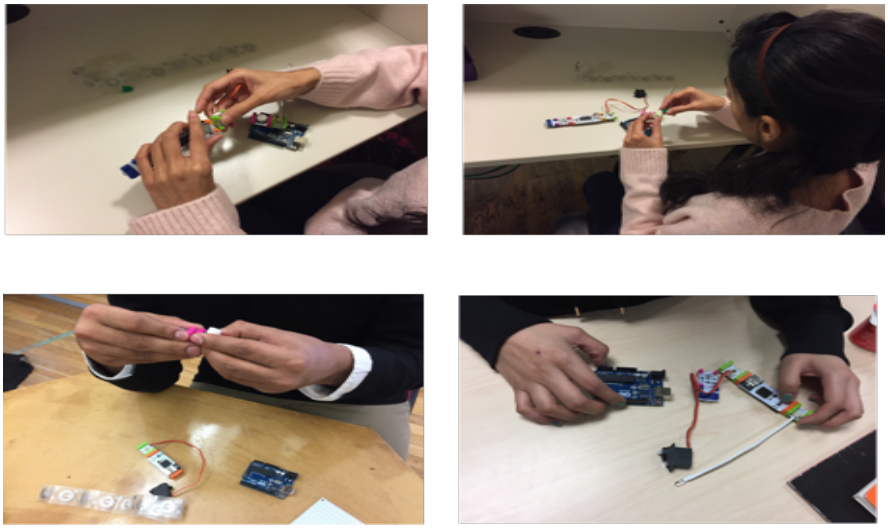


Figure 19 Participants Attended Design Workshop On Dec.7~ 11, 2016 at the OCADU Digital Futures Studio

- *Design consideration*

Throughout the workshop, approximately 80% of participants could not complete Arduino's "Hello World" activity, despite watching the instruction video. Participants felt the Arduino toolkit was "too complicated," and "too much to learn." The most challenging part appeared to be wiring up the sensor and the board even though there was a detailed picture to show each pin. The language used in the video was difficult to understand. The majority of participants said this toolkit should be for the more professional users and hackers, not for the general user. Only two male participants successfully demonstrated the project, and one of them has a background in coding. "The Arduino board," he said, "gave me more flexibility and unlimited creativity." The other successful participant said that if given more time and if he had more energy, he would be willing to try more

projects; however, he also admits using the Arduino toolkit is very “highly demanding as a daily activity."

The design of the Littlebits toolkit is very user-friendly, certainly more straightforward for participants to understand how the kit works. Littlebits’ mobile application allows users to code in a much easier way, shortening the learning curve, and highly increasing the desire to try this novel toolkit. The majority of participants did note that the clarity of language of the instructions was still hard to understand, and not everyone understood the terms “threshold” and "number bit” in the context. Another barrier to entry is the cost of the Littlebits toolkit. Participants felt the price was not affordable (CAD 150) in daily basis. Marketing was also considered a barrier as the company promotes Littlebits as educational tools for children rather than for curious adults to use in their daily lives.

FlipFlic is most close to what Millennial expect and find compelling for their everyday needs. FlipFlic folds all the electronic parts into one piece while maintaining an elegant design and appearance without destroying their home’s existing infrastructure. Also, the installation does not need professional assistance and is simple to do on one’s own. The controlling device can be set up through their smart phone mobile application easily as well. There were a few barriers participants felt prevented them from considering purchasing FlipFlic for themselves. Firstly, the price of the product was not considered “good value for

the money." Additionally, the multiple-usability is needed to increase the perceived value, and participants felt that opening and shutting their curtains is not a necessity for convenience; also, this task that does not hit the "pain point" like the home mess and disorganization does as discussed above.

To summarize, in considering the future SMARTKIT design, the key features which should be included are: (1) minimal elegant hardware pieces that does not require much wiring and/or professional installation; (2) the ability to easily set-up with and connect by smart phone mobile application that is easy to operate; (3) an affordable price with multiple-task functionality and limited, customized flexibility; and (4) scalability to customize the use scenarios.

4.2.3 Phase Three: Implementation

Based on the results from the ideation phase, the potential solution to organize home should address the function of the enchantment in identifying the consumables' time, location, and state of use in the home environment. Consider the design requirements from the "hacking illustration." The prototype should include three major parts: (1) a minimum of hardware pieces; (2) SMARTKIT toolkit system with mobile interface; and (3) installation instructions. The prototype will be iterated in three cycles which should emphasize representatively: (1) functionality: (2) design; and (3) ease of assembly and installation as well as cost.

- *Process of Prototyping SMARTKIT*

The prototyping stage includes three cycles: (1) functionality prototyping, including hardware and system framework; (2) design prototyping involving mobile interface and hardware appearance focusing on the layout and stylish template; and (3) installation instructions and cost considerations concentrating on the modularization.

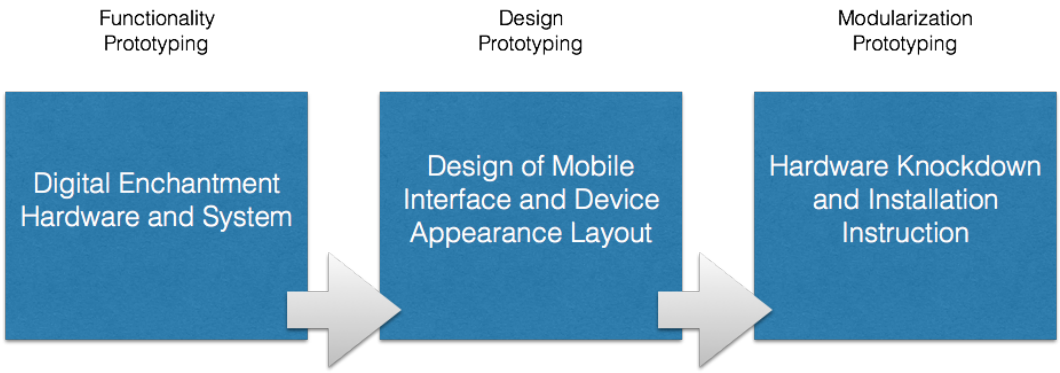


Figure 20 Process of Prototyping SMARTKIT

Prototyping Cycle One
Function prototyping – enchanted hardware piece and mobile application system

Two major parts need to be completed. One is hardware, and the objective of this stage is to create an enchantment which can function well to identify the object's location, time, and state of use. The enchanted hardware piece is then triggered, sending a reminder to the user as to the location and state of use the object in question is. The other piece is a software system, and the goal is to

create a mobile software framework with the function of uploading data that will trigger the reminders in the hardware.

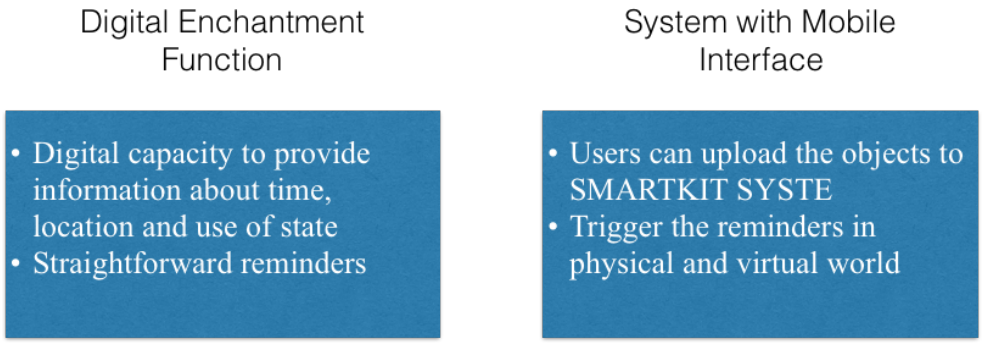


Figure 21 Function Description of SMARTKIT Beta

- *Digital enchantment*

Technology chosen

Many of the IOT projects have proved the advantage of the RFID technology in the home environment (Gubbi et al.,2013). RFID is the process by which items are uniquely identified using radio waves and primarily operates in three frequency ranges: low frequency (LF) 125 -134 MHz, high frequency (HF)13.56 MHz, and ultra-high frequency (UHF) 856 MHz to 960 MHz. NFC is a branch of high-frequency (HF) RFID, and both operate at the 13.56 MHz frequency. Passive RFID tags are tiny electronic components with an integrated circuit and a small antenna usually sealed in one small package. Another advantage is the tags are energized during access by the reader via electromagnetic induction so that there no battery needed. The reader is another

electronic component which provides the energy when they connect in a short time and communicate with each other (Schmidt et al.,2010).

The application of NFC-related technology is common in logistics, inventory management, and other industries, and it is fast approaching mass adoption with smartphone use soaring in our daily lives. The majority of Android phones have a pre-installed NFC antenna. Writing information into an NFC tag is as easy as texting. What is more attractive is the cost of both the NFC tag and tag reader is affordable for almost everyone as well as flexible and customizable to your preferred shape, size, and material. NFC technology is not new, and because it is approaching mass adoption rates, it should be considered yesterday's technology. However, it still has an enormous potential to demonstrate a compelling user case for use in creating a mess-free home.

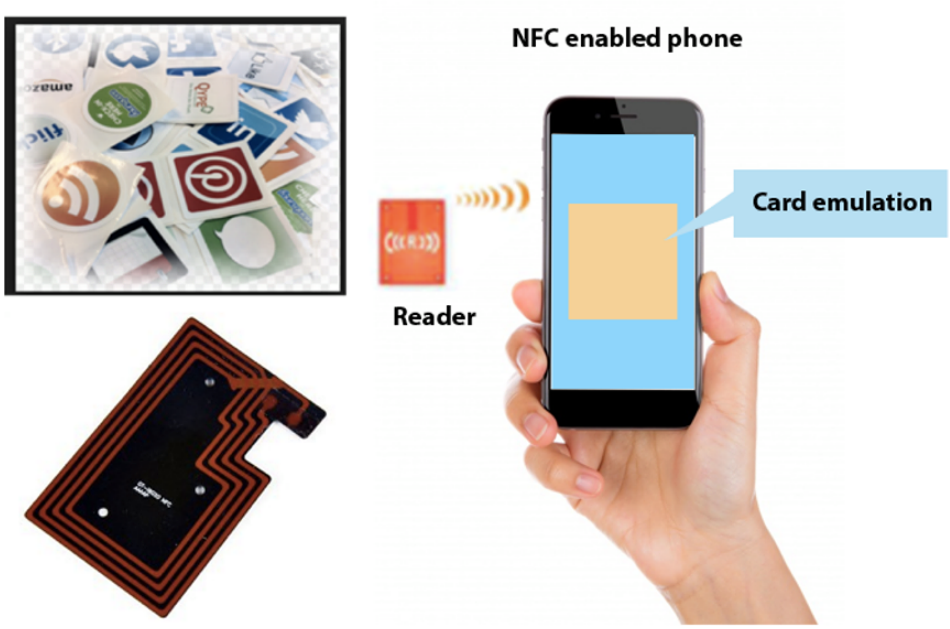


Figure 22 NFC tags, reader antennas, and an NFC-enabled smart phone

As indicated in the inspiration phase, the potential solution for home organizing chosen by participants was the smart food tag, smart drawer, and smart closet. One challenge of NFC technology in solving our organization problem is the size and the distance of the antenna's capability. Technically, one singular NFC reader can identify the object within 5cm * 5cm, which is the size of RDM8800 antenna. However, the average, standard size of a drawer is 20cm depth, 51cm width and 41cm length (IKEA ASKVOLL), which is too large for one NFC reader to cover. There are, however, a few ways to increase the size of the antenna. One is to replace the reader into

ultra-high frequency mode with the caution that the cost, the price point, might not be acceptable or accessible for household users. Another is to enlarge the single antenna size, and the price is more customer-friendly. Another inexpensive solution is to duplicate the small size NFC antenna in a matrix so that the NFC reader can be scalable. For SMARTKIT case, the key point is not about technology but the digital experience created in an accessible and affordable way through DIY approach. Hence, I decided to use the currently available components to simulate the scalability of the NFC reader modules.

The RDM8800 card reader is a module based on the PN532 chip customized for 13.56Mhz NFC RFID card, compatible with RDM6300 interface, which can read data directly from the serial interface (Appendix D: RDM8800 datasheet). Unlike ordinary RFID modules, the RDM8800 integrates the LGT8FF8A chip, which is compatible with the Arduino library. Thus I can modify the firmware to suit our needs. The Itead studio has also released the source codes of RDM8800 firmware, and users can make a subsequent development based on it.

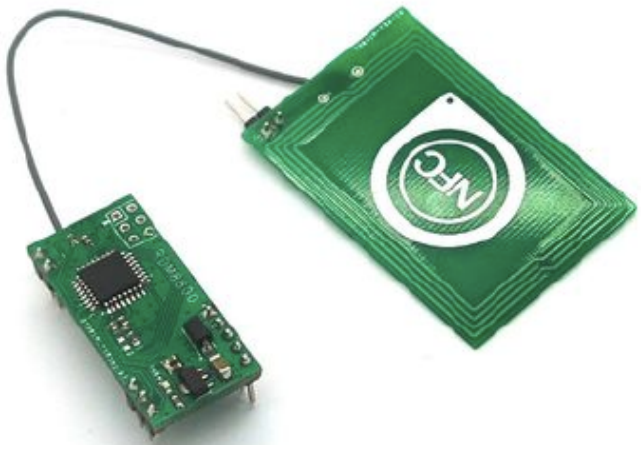


Figure 23 NFC Chip and Reader Module

The center of the SMARTKIT system is the microcontroller necessary to scale the capability of the antenna. With minimal customization, you can add multiple RMD8800 readers into one controller. With the first prototype, a Photon Particle microcontroller was chosen for the test because it cost only $19 and worked with a Wi-Fi connection. Another advantage is that it can work with the Arduino library and connect with an RMD8800 reader. The only challenge is the output voltage which is 3.3, and lower than the minimum requirement for RMD8800. Therefore, I used 4 AAA batteries to provide power supply to it directly. The following diagram (Figure 24 & 25) illustrates how the hardware worked. In the first round, the device worked well using single and multiple reader modules and antennas.

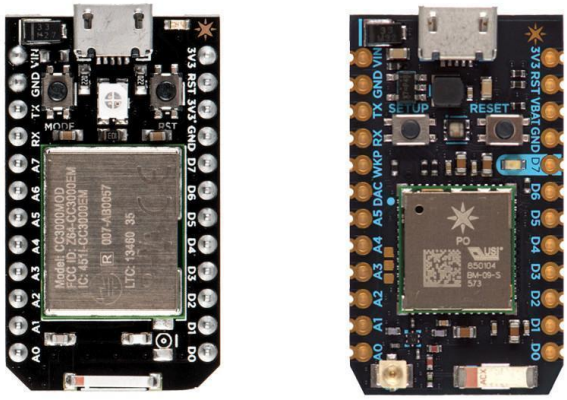


Figure 24 Photon Particle Microcontroller

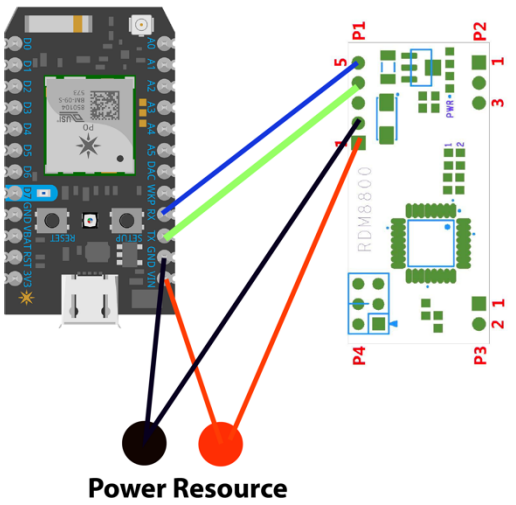


Figure 25 Photon with RDM8800 Circuit Structure

Considering the request to use one single microcontroller to collaborate with multiple RDM8800 chipsets, I also tested the Photon RedBoard, which works under same hardware firmware and but the size is three times larger the Photon Particle, which provided the extra space to hold chipsets like figure 26.

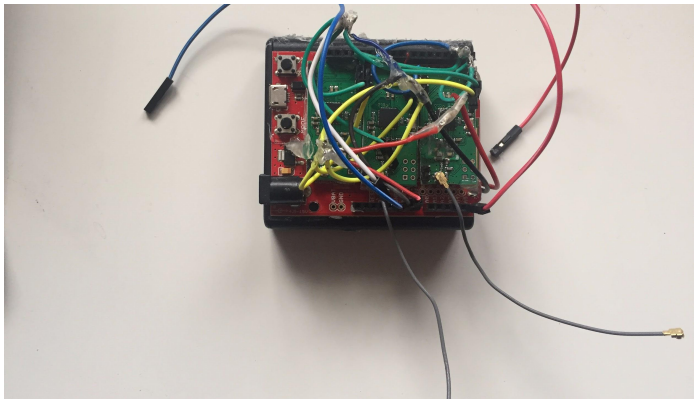


Figure 26 Photon RedBoard with multiple-RDM8800 Chipsets

- *System with mobile interface*

The aim of the system is to gather data from the enchanted objects, manage the variables, and provide reminders to users. Hence, the system should

include three essential parts: (1) the mobile interface which allows end-user input or uploads the data about everyday objects; (2) the invisible system called SMARTKIT cloud, which manages the data change; and (3) the reminders which notify users when the data changes in a certain way. The system manages objects such as food, clothing, and small items by providing following three functions: (1) advising where stored objects general position or location is by detecting objects located in specific drawers; (2) notifying what food is available and fit to eat by tracking freshness and time spent in the refrigerator or home environment; and (3) managing favorite clothing by tracking the frequency the clothing item is off and away from the clothes hanger sensor area.

1. System structure

Considering the volume of everyday objects in the home environment, the SMARTKIT system should have the ability to keep track of a vast number of small and inexpensive items. Sources of data should assist in classifying the household items, broadly segmented into three types: (1) stand-alone; (2) aggregators; and (3) collaborators (Ganesh et al.,2014). Stand-alone applications are woven around a single device that may host one or more sensors to capture data from the surroundings. Collaborators integrate multiple stand-alone applications in a similar context to provide a user experience that is more than the sum of its parts. Aggregators gather insights from disparate connected systems (collaborators) to achieve a larger goal. The following diagram shows the overall

structure of the designed system as presented, and the three components come together to prompt the service to the end user that fit a need or solves a problem.

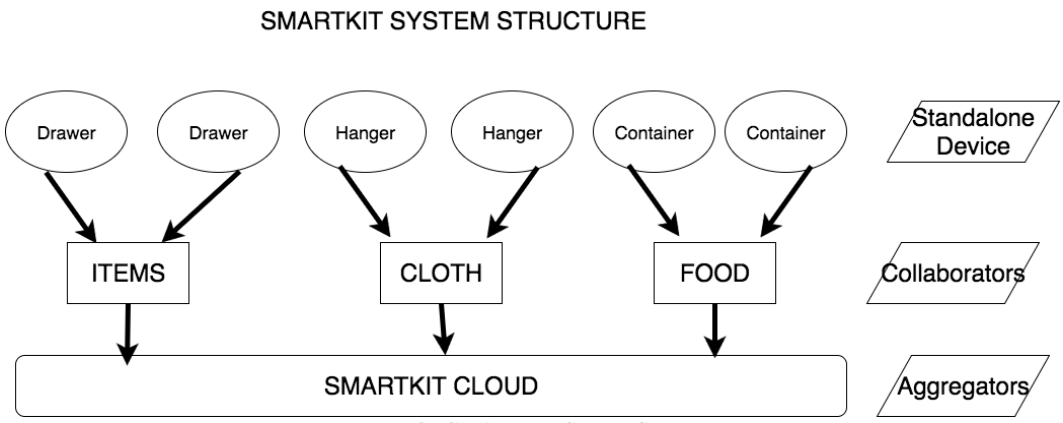


Figure 27 SMARTKIT System Structure

2. Data collection / input

The application of QR code is common in the current market, and it is easy to gather information by scanning QR codes on clothing, food, and any other household objects if the technology is available. Taking clothing retailer Zara as an example, scanning a QR code with a smartphone will give you the information about a garment's colour, size, material, and washing instructions. Another familiar way to upload data is to take a picture which more accessible than QR code, but the downside is that users have to key in the specific information manually. The interface allows users to upload the data by using both of these ways.

3. Trigger the reminders

Voice and picture searching are both accessible and familiar ways for people searching for information on their smartphones. The system followed this trend and added those functions. Reminders should not be too disruptive and must be kept at a minimum, remaining within the original context and not to create new ones. The reminders and reminder notifications should be a mobile phone based application relatively straightforward and easy for a user to be notified and access set-up for these notifications. In the given scenarios at home, light is the simplest way to indicate the notification.

4. User flow

To summarize how the system works, the diagram below captures and concludes the details. When users return from shopping with new items, be they clothes, food, or daily household objects, they can update the new item into the system by scanning the QR code or taking a picture of the item and type in the corresponding information. An NFC tag is then attached to store the new information input to finish the data collection. At the same time, the system provides users three types of tracking, which are location, time, and the state of use. For example, in the case of food, they can track the NFC tag by time so that they can monitor the freshness of food. If users need to find the general location of the item, they can search by pictures or voice, and then trigger the reminders in the physical and virtual world.

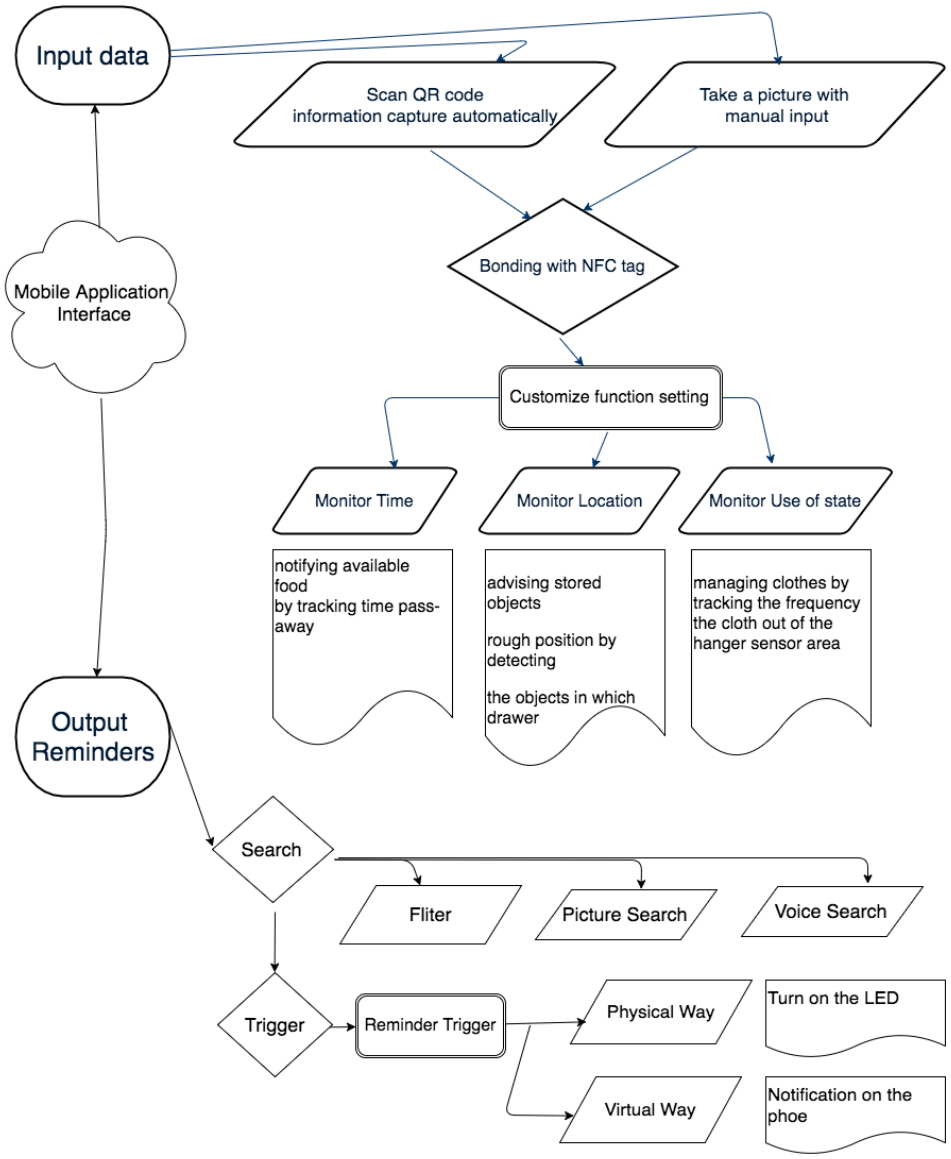


Figure 28 User Flow of SMARTKIT

5. Light application based on API of WeChat

API is a modern term referring to application programming interface, which is a set of subroutine definitions, protocols, and tools for building

application software. In short, the API allows different applications to use one or more of their functions and call each other's program data. In this way, the third-party developer can save time and money; meantime, the large software ecosystem owners such as Google, Facebook, Twitter, and WeChat. Can broaden their technology and service by recruiting free labor to maintain active users and keep up the volume of traffic. API is a win-win strategy.

As the biggest cross-platform social network, as of May 2016, WeChat had over a billion created accounts worldwide and currently 864 million active users (BI Intelligence, 2016). WeChat provides open API, including QR code scanning, photograph, and voice recognition, which provides the strongest capability for third parties who can develop lightweight "apps within the app." This allows users to minimize the time investment on mobile application developing. SMARTKIT applies Java, HTML5, and Php to code within the WeChat ecosystem.

- *Summary of SMARTKIT Beta*

In this stage, the prototype can work functionally; the data input is smooth, and the LED can be ignited correctly based on the user's demand. By showing this prototype to the potential user, having a real thing in hand, the majority of responses were positive, and they like the way the system worked and what its future functionality would be. Concerns were raised around the whole experience, such as reliability, cost, and the design to eliminate household messiness.

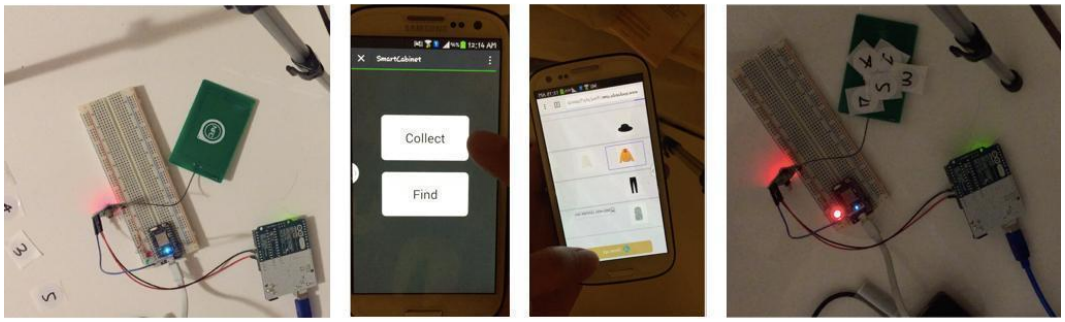


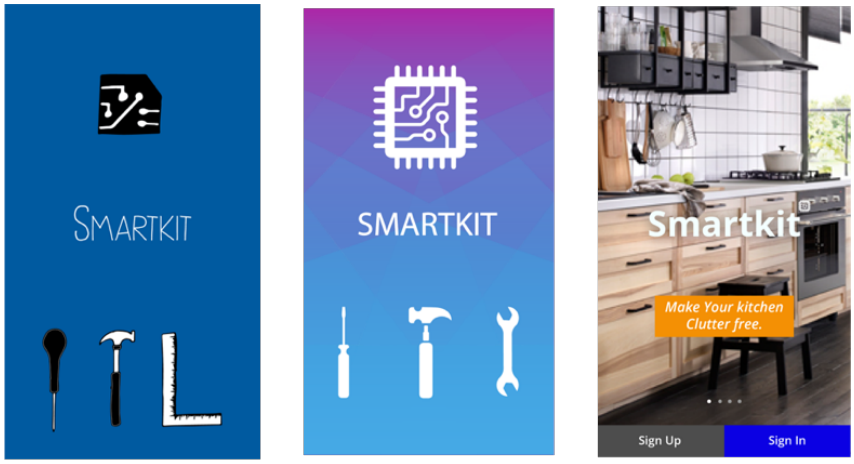
Figure 29 SMARTKIT Beta

Prototyping Cycle Two
Design prototyping – mobile application interface and hardware appearance

- *Mobile interface design*

In this cycle, the concentration of the prototyping shifted from functionality to design which included interface design and SMARTKIT hardware layout. Following the user flow as indicated above, three different interface designs were created, and potential users were asked to vote for their favorite. Style A is a doodle. By using natural abstract lines, the design implies that the tool is as uncomplicated as a children's toy and that everyone could use it as doodling and scribbling are most often associated with young children. Style B is sketching flat, which is the very popular style used in contemporary design applications found in Google, Apple, and Microsoft products. The gradations and various flow try to match fashion trends by considering some scenarios related to how we dress. Style C is photography, representing minimalism and Scandinavian design. The

photography applied to the application corresponds with the IKEA aesthetic and reminiscent of a clean, well-organized and clutter-free home. The result of user voting shows that over 65% of participants love the photography of Style C.



Style A- Doodle | Style B- Sketching Flat | Style C- IKEA photography

Figure 30 Three Different Interface Style Designs

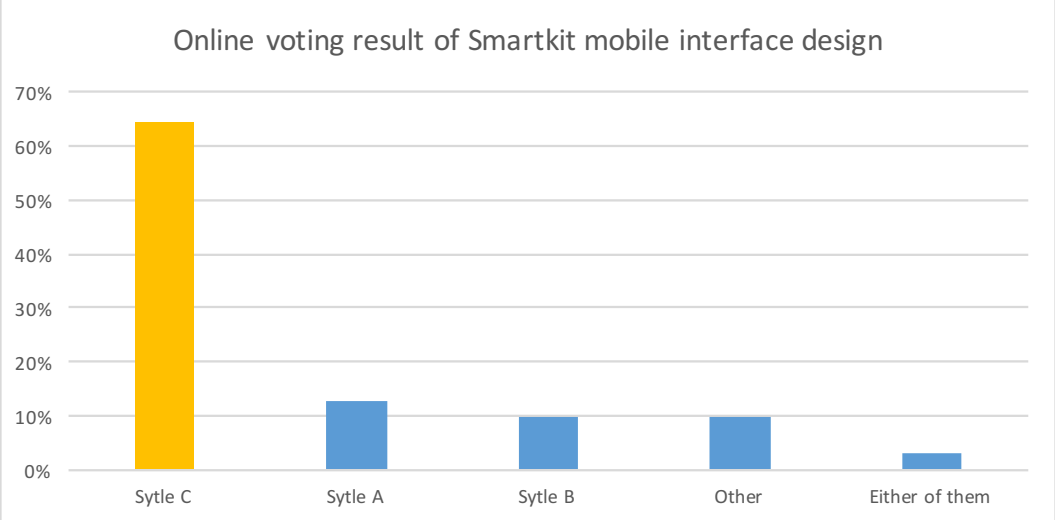


Figure 31 Online Voting Result of SMARTKIT Interface Design

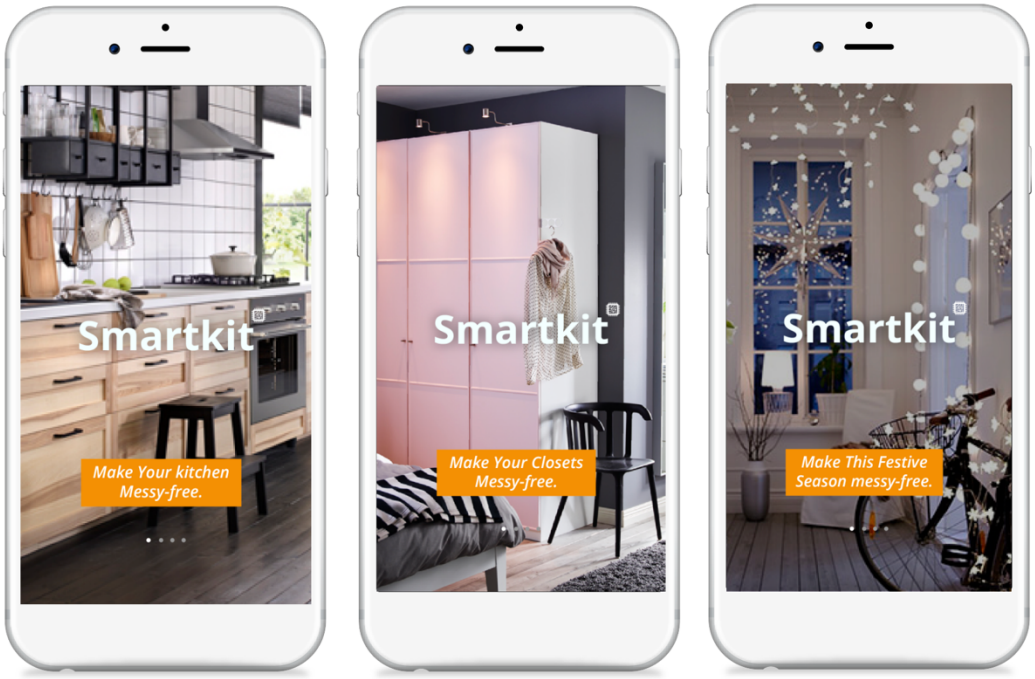


Figure 32 SMARTKIT Mobile Interface Layout-1

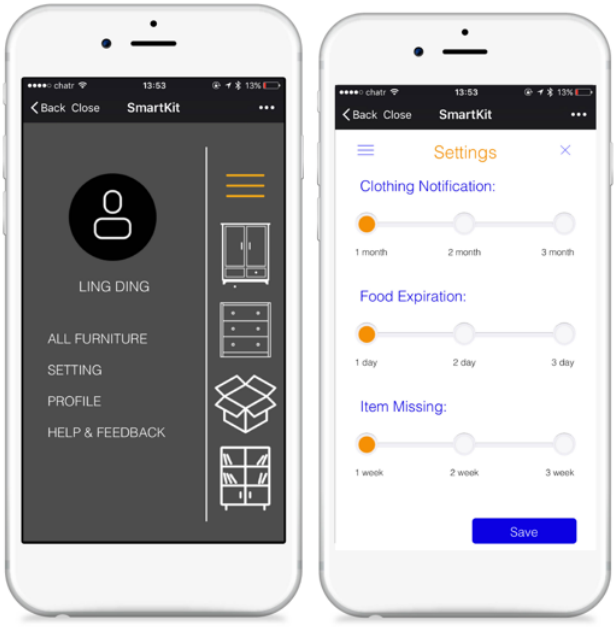


Figure 33 SMARTKIT Mobile Interface Layout-2

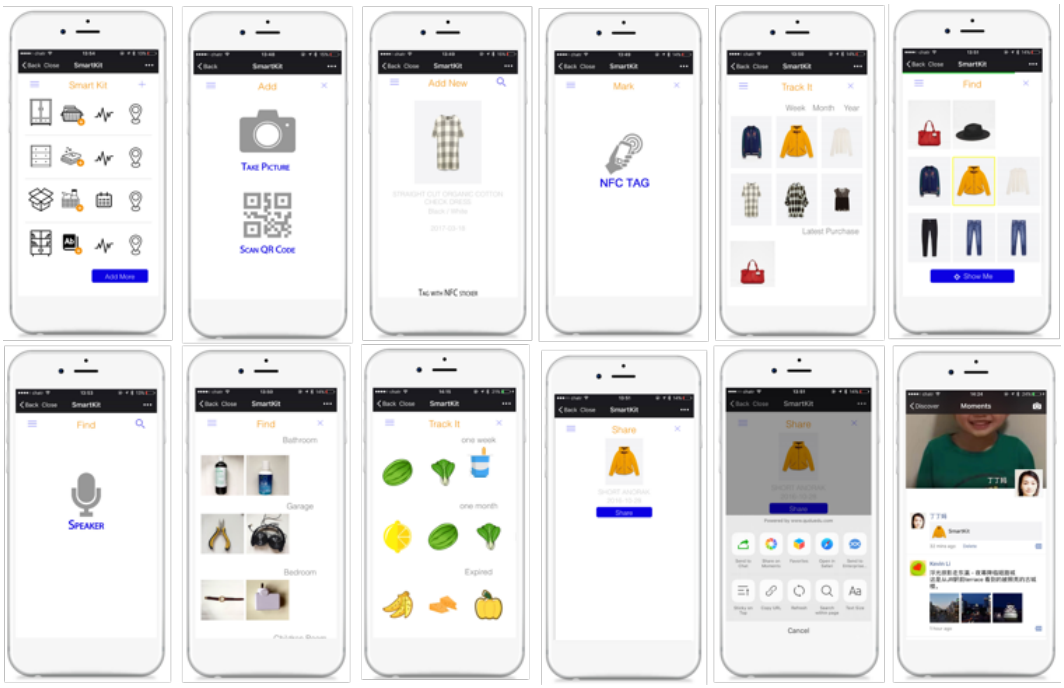


Figure 34 SMARTKIT Mobile Interface Layout-3

- *Hardware appearance design*

The guideline and ideal of the "enchanted object" are to "remain the object that continuously serves its original purpose but let it also have something extraordinary or new capability on top (Rose 2014)." Hence, the key to designing the enchanted object is to find a means to digitally enchant the ordinary object so that it is sure to send out the reminders in a natural way, enhancing the enchanted

object's seemingly magical "intuition." Take a cabinet, for example, the front part of a cabinet or set of drawers which is closed and solid, making the item within it invisible to our eyes that are looking for it. People have to open and close the drawer when they are not sure what is inside or where the target object is. This can be very time-consuming. The drawer handle is the most frequently used part, so imagine if the handle can send reminders by blinking light, reducing the number of times the cabinet drawers are opened and closed, and logically eliminate the time of searching. Here the NFC reader consists of two parts—the NFC chip and antenna—connected with each other by wires. Inspired by Littlebits, each wire could be identified and installed by colour. The fewer wires mean less confusion, which helps to keep the mechanism simple, reducing complexity. Another lesson from FlipFlic is to contain all the electronic components in small compartments, increasing simplicity by removing the necessity for users to understand how the mechanism works. It could be argued that the end user cares more about the problem-solving aspect of the device, not the technical know-how. Hence, the hardware of SMARTKIT can be divided into three pieces: one is the enchantment box, the second one is the antenna, and the last one is the handle with the LED light (shown in Figure 35).

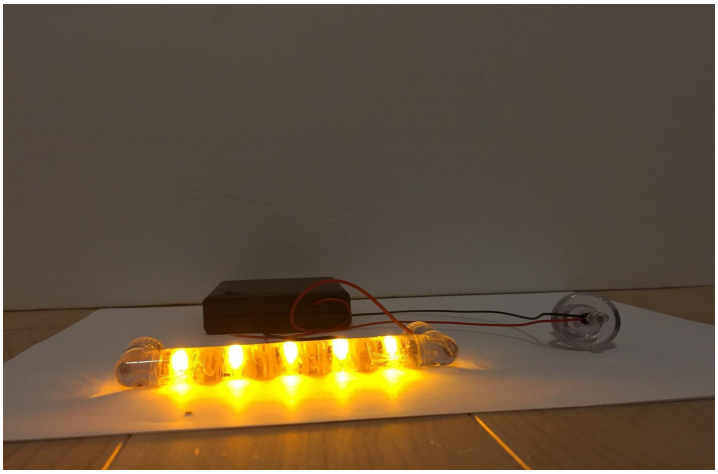


Figure 35 Handle with LED for Reminding Beta

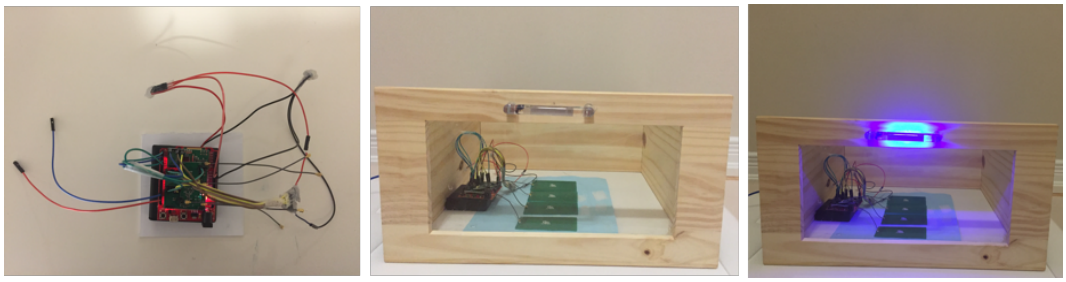


Figure 36 Smart Drawer Beta

A similar philosophy can be applied to the design of the smart hanger and the food container. The LED light could be added into an easily visible part, like the top and the front of either piece, but able to hide the digital enchantment into the existing structure of objects and putting the antenna around the side of the edge (see Figure 36). Clothes hangers cannot use the same design because normal hangers are very thin and the middle part is cut-off. New design is needed to provide the support for the device.

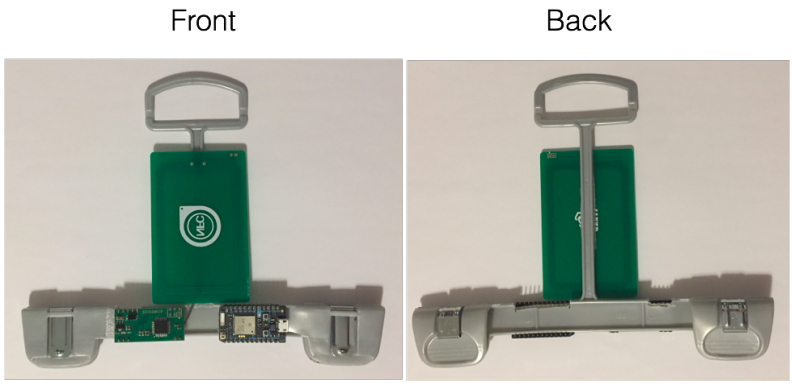


Figure 37 Smart Hanger Attachment

Figure 38 Smart Hanger Beta

Figure 38 Smart Food Tag_ NFC sticker

Considering the food category is predictable, and the frequently consumed food is similar. Therefore, a simple way to keep track of the freshness of food is to create a pre-written NFC tag with an expiry date setting as well as allowing end-users to customize it for particular circumstances. Figure 38 demonstrates some pre-written smart food tags. By tapping with an NFC-enabled cell phone or smartphone, the system can identify the newly purchased food and activate tracking it for freshness.

The goal of SMARTKIT is not to design several different settings but to create a kit which could enchant different furniture with the same design and mechanism. With this goal in mind, the design of the clothing hanger enchantment was modified to keep consistent with the drawers' enchantment in the next prototype cycle.

Prototyping Cycle Three
Modularization prototyping – knocked-down, installation instruction, and cost consideration

Modularization means taking an activity and dividing it into small, manageable pieces or modules (Norman,2008). In spite of their complexity, multiple activities can be supported with appropriate design in such a way that the user never realizes the complexity of the task or the device. With the proper conceptual model and with the proper compartmentalization—so that only the displays and controls relevant to the current task are the central focus—the device always looks simple, regardless of its inherent complexity. "Knock-down" is a term to describe the furniture that aims to be easily assembled by the consumer, not requiring a professional. Knock-down is also known as ready-to-assemble. The most classic case of knock-down furniture is IKEA, whose founder Invar Kampar realized "knock-down" came to be a significant cost-saving innovation bypassing the transportation and assembly fee to customers. What Kampar did not expect was how passing along assembly responsibilities to buyers brought them joy and love for these products. This business philosophy has been applied broadly in the maker movement. Two major reasons for the success of the knock-down model is system structure, and the other is the straightforward and easy to follow assembly instructions. In SMARTKIT case, the hardware enchantment was fairly straightforward and divided into three parts as mentioned in appearance design part: (1) a small box with digital enchantment, (2) the antenna, and (3) the

LED light reminder.

Figure 39 Smart Drawer Knockdown

Regardless of clothes hanger size, the DIY enchantment which attached to the one side would be smaller, and it also needed to be hung in the air. The previous prototype achieved the functional goal and fit the thinness of the hanger, but SMARTKIT needs to keep the knockdown consistency. After several attempts, using the clip to attach the enchantment worked well (Figure 40). The only solution to this kind of design is to increase the thickness of the hanger, which is not aesthetically pleasing. However, the enchantment is the same regardless of the actual size.

Figure 40 Smart Hanger Knockdown

The challenge would be creating an accessible, readable, and

understandable installation manual for the target audience who, with average digital literacy, instructs them in how to install and use it correctly. Instructions for putting things together or understanding how things work are notoriously frustrating (Daniel &Tversky,2012), particularly digital product instructions with 80 pages of technology information, which do little to clarify how to use it (Story, 1998). In fact, the writer of these instructions is not someone with a thorough knowledge and understanding of how the product works. Knowledge translation is key to fully comprehending how to use complex digital products. Echo this finding in the IDEATION phase where the majority of participants involved since the beginning of this research project mentioned that the language (including technical terms and format like video) used in the instructions was hard to understand.

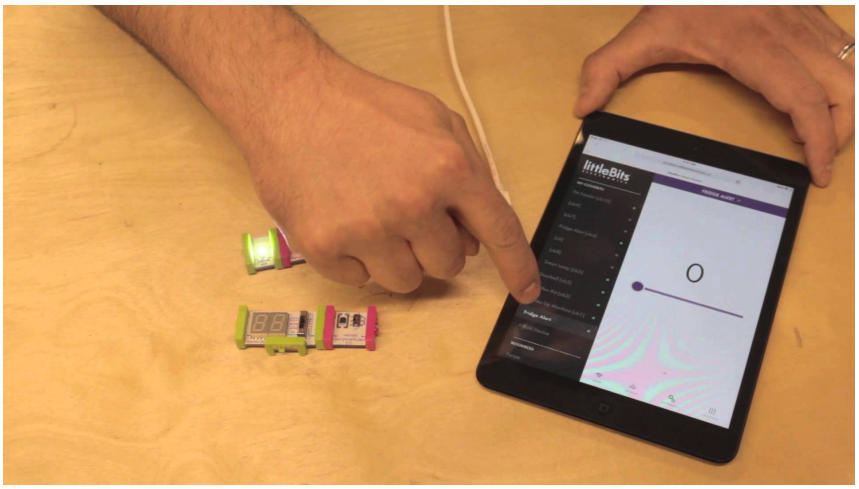


Figure 41 Littlebits video instruction(Littlebits 2015)

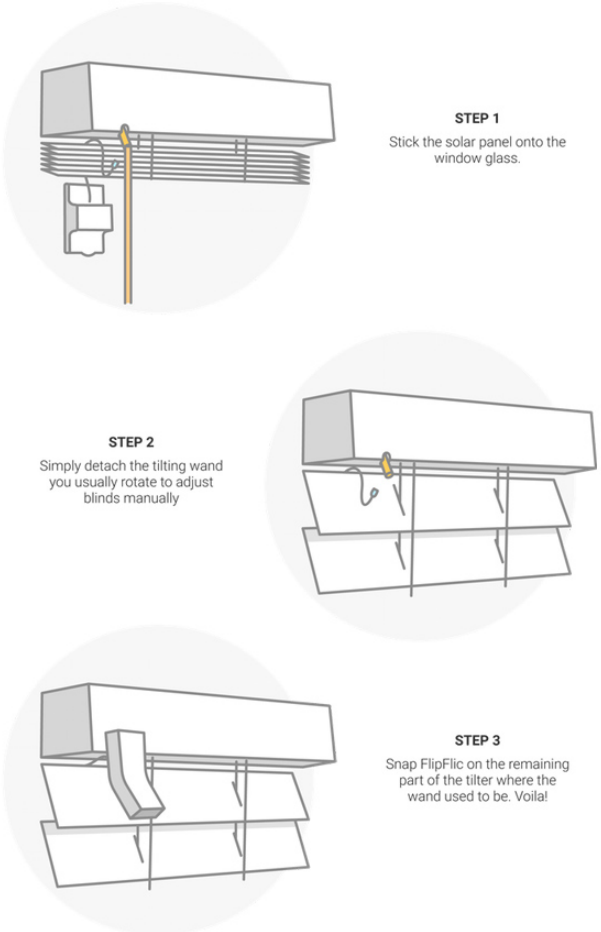


Figure 42 Flip-flic diagram instruction(Flip-flic 2014)

In previous research, Flower and Hayes claimed that for instructions, images often worked better than text because they are easier to imitate (1984). One series of studies on three to five-year-old children reveals that even young children can easily imitate actions that are demonstrated to them visually. These studies also show that humans are primarily goal-oriented and if they are shown a series of steps they will often find a faster way to come up with the same result, taking shortcuts to deviating from the confirmed action to get to the goal more

quickly (Flower & Hayes, 1984). The structure of users' instructions usually involves three parts, which are an introduction, a middle, and an end, and the function of the central part is to describe or depict the actions step-by-step. Diagrams were regarded as fundamental, and redundancy of depictions and descriptions were found to be desirable (Daniel & Tversky, 2012). These design principles have broad applicability to many kinds of explanations (Daniel & Tversky, 2012). Another fact that may influence wider adoption is the perceived value (as mentioned in the discussion) around marketing research. Rarely do instructions indicate the benefits of an item or program directly? Creating a compelling user case will increase the desirability of a product. By synthesizing the previous research, using IKEA's product instructions for reference and adding new creative solutions to the instructions, the experimental SMARTKIT's final prototype, as seen in the diagram below (Figure 41 and 42). Another advantage was the total hardware cost is under $40 Canadian dollars by using the currently available hardware components.

Figure 43 SMARTKIT Final Version_3D Modelling

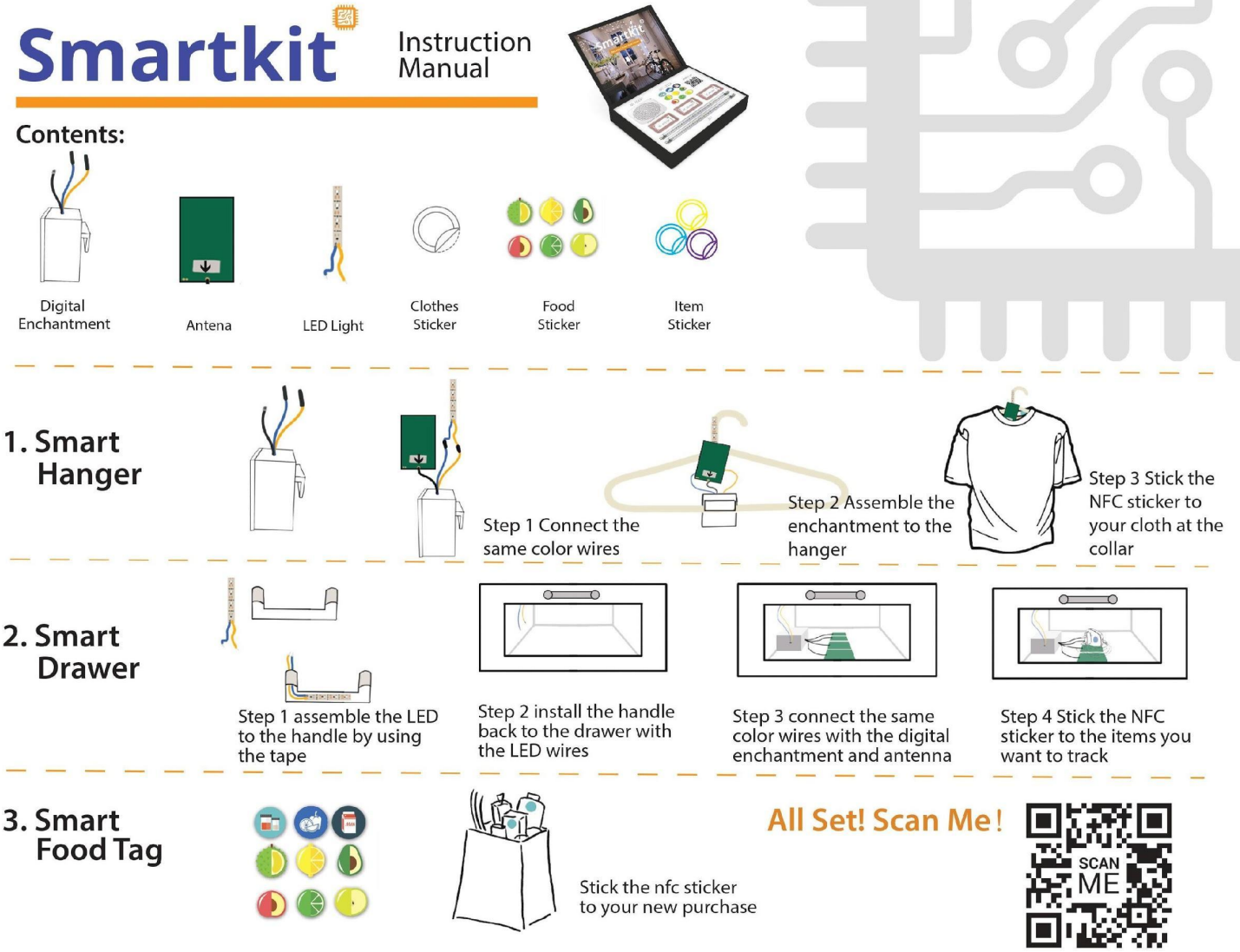


Figure 44 SMARTKIT Manual

4.3 Response to Research Questions

The goal of this thesis project is to validate my hypothesis: that DIY enchantment could be a democratic solution to help ordinary people to organize their homes better. I conducted the final user testing to converge the response to the research questions.

4.3.1 The procedure of final user testing

The last cycle of iterative user testing was designed to pinpoint preference and usability issues for end-users within this research to respond the initial research questions. In this user testing period, in-person interviews and physical interaction were required. A total of 8 potential users age from 20-35 attended the final user testing at OCAD U's Digital Futures Studio between February 17 - 20.

The audio recording was used during the entire user testing process with participants' consent. Raw data gathered in iterative user testing was preserved in an encrypted hard drive for 24 hours before permanent deletion. Photographs were taken of users' hands or backs, never their faces, to record how people played with the prototype. No identifying aspects were filmed or included. Background and gender were not specifically mentioned and will not be considered differently.

This user testing session focused on user feedback about the design of SMARTKIT and its performance. The testing was included: (1) functionality

sufficiency, the system's overall performance, and usability; (2) aesthetic appearance in both of user interface and hardware layout; (3) DIY approach in term of installation challenge and learning curve as well as (4) cost. The software and hardware parts of SMARTKIT are evaluated as a whole.

4.3.2 Data Analysis and Result

[1] Functionality and usability

All the participants agreed that the overall resolution of home organizing by hacking through DIY approach is moderate and decent at this stage. The three user cases demonstrated by SMARTKIT are compelling and attractive to solve "messes" in our daily lives. The mobile system operated smoothly, and the functionality such as uploading a picture, scanning a QR code, and triggering the reminders worked efficiently. Participants love the QR code function and claimed it was a great approach rather than manually keying in each item because the number of clothes, objects, and food in their homes is enormous. Manually inputting the data would be too much effort and too time-consuming. Two users were familiar the sharing button within WeChat, and they agreed that this social functionality could reduce the waste by exchanging unused items between the acquaintances.

The following elements could improve in the future. (1) The connection of the wires could be more secure if the wires were not exposed on the outside. (2) Multiple screens would be added. Two participants suggested that the interface

also could include a tablet version and a desktop version because the majority of users noted that their smartphones are the most commonly misplaced item in their homes. In that scenario, the tablets and desktop, or even the laptop computers, at home would be supplementary devices to keep track of their consumables. (3) One final thing the participants mentioned is the need to customize the functionality of the system because in some cases, they did not need to identify the location, time, and the state of usage at the same time. For example, for the storage of food, people do not need to know the location. However, the storage volume would be more valuable to show. Ideally, if the system can provide more than one format for informing the user of the information required, such as triggering notification through a sound, it would benefit people who are visually impaired as well as increase the enjoyment and ease of use and perhaps inspire new creativity.

[2] Aesthetic appearance

The aesthetic appeal of the mobile application was desirable and made the user feel warm and home-oriented. Four of five loved the overall layout and commented that it was ideal for navigation. The DIY enchantment was easy to install but the potential users expected the size to be smaller and the aesthetic feature of enchantment would be polished, especially for the clothes hanger. The current size would be three times thicker than the usual one due to the battery size, which occupied too much space. Another participant even asked why the

hardware has to be a square box rather than other shapes. The antenna should be able to be customized into different shapes, sizes, and environments.

[3] DIY approach

All participants installed the DIY enchantment successfully without panicking, and participants felt the instructions provided great insight and a surprisingly lower level of complexity to install the DIY SMARTKIT by themselves because the wiring was identified by colour and the requirement for connection was a mere press-in action. There was no need to determine the function of the wires, electronic components or the links. Attaching the enchantment to the furniture also was relatively easy since all of the actions required were to remove the tape cover, stick the LED to the surface and reinstall back to the original position.

Three participants said, “it is a very smart move to use a handle with LED as reminders because it does not change anything, only enhances it”. “The installation is as simple as playing with IKEA furniture without learning new skills behavior

[4] Cost

Over 80 percent of participants mentioned that the kit-setting do add more perceived value than the single-setting product because they can peruse more possibility on one kit. If the sale price is less than $50 Canadian, the potential target audience considers it affordable. Almost all participants emphasized the

price was a key consideration for them to seek new solutions for home organizing. This finding also reflected that the current smart device is too expensive to adopt as daily use, according to the response to the question "what would stop you from adopting smart home technology at home?"

Participants not just concerned the cost of purchasing but also installing, maintaining, and scaling the system at home. Although the expense of a single device seems reasonable, when users consider multiple devices required for the whole house and organizational needs, the cost would be enormous and critical in the end. Hence, how to scale at a lower cost would be an area for future improvement.

[5] Inspiration

Likewise, SMARTKIT stimulated more creative solutions beyond the three user cases as exhibited in the instruction paper. One participant behavior is that they could not stop thinking about and suggesting new ideas. This participant was able to relate to his previous experience in the retail clothing industry, suggesting that if retailers such as H&M could use the same smart clothes hanger to track the behaviour of shoppers, it would dramatically increase the productivity of business analysis. Previously the researchers used cameras to track the path of consumers, recording how they shopped in the store. Results were drawn from analysis of the footage. By using smart hangers, they could provide real-time analysis on the choosing, fitting, and purchase behaviour of customers. Following

this data, retailers could modify store displays to match these preferences. Another participant mentioned that, in addition to managing daily consumables, SMARTKIT could also be a solution to deal with house insurance and inventory. It was arduous to write down a list of all the property, and the prewritten smart tag could reduce the workload of labelling.

4.3.3 Reflection

From the literature review, IKEA was able to keep the sale price affordable for everyone by moving the major cost of assembling and transportation to the user. Meanwhile, the DIY-assembling added the extra enjoyment and accomplishment to the consumer. Beyond that, by providing the standard sim-raw material to hack, the “free labor” lead to “more love”.

SMARTKIT tries to apply this democratic design philosophy in the digital context through human-cantered design. Inspired by the enchanted objects, the normal daily-use home furnishings such as hanger and drawer were enchanted by adding new connectivity to provide tracking and locating service to deal with home unorganizing. Then, stimulated by the DIY hacking, this new enchantment was decentralized based on the current potential consumer’s hackability in aiming to pass the assembling cost to the end-user. Eventually, a digital kit was created to provide the multiple usages in a less expensive solution to organize home consumables.

This plausibility of a democratically designed SMARTKIT not only allows the potential consumer able to engage in a familiar scenario but also let them see the possibility beyond the current challenge and imagine new possibilities for the future smart home.

Overall, the performance and completeness of SMARTKIT received moderate confirmation and demonstrated the possibility of the democratic design in the digital context of smart home.

CHAPTER 5 – CONCLUSION

5.1 Future Works

Future studies on DIY enchanting could leverage different solutions for mitigating home organization such as expired cosmetic products, our many tools, and books. The similar framework I mentioned in the literature review section also can be applied to other daily-use objects such as clocks, umbrellas, and the paintings which were previously enchanted by professional individuals, startups, and large organizations. The key barrier included price, the complexity and computer literacy which are too high to be democratized.

Another equally important direction that could be discussed further is the functionality in socialization. In this paper, I used WeChat as the leading platform in which to integrate the IOT products within the current social network. I am firmly aware that a social function for SMARTKIT could have a potential for reducing waste and be environmentally friendly as a portal to exchange food, clothing, and unused items similar to sites such as Kijji.com and Letgo.com. Also, the socialization function could be scaled into different platforms such as Facebook, Twitter, Snapchat, and Google Plus.

When the static objects are activated and connected, one profitable byproduct will be the emergence of new services like personal shopping consultant and healthy eating services. In this way, the traditional grocery sectors, retailers, and traditional manufacturers such as IKEA and Zara will enter a brand

new industry and compete with the giant information and technology players like Google and Apple. During the research, I found IKEA's new digital movement such as creating a self-assembly furniture robot and the 2020 projection mapping kitchen were using very advanced technology. However, rather than investing in brand new products and entering an unfamiliar business, we could add new digital enchantment and enhance the original functionality of existing products. The cases I investigated in this thesis indicate there is a large opportunity to bridge those household merchandise suppliers to the new arena of Information and Technology by taking advantage of previous assets. Imagine, shortly; the lipstick could know what dress the consumer plans to wear, and use data to tell which colour is the best match. This use case could be compelling to millions of users.

Even though this thesis does suggest that the technology could be democratized and simplified to match the "hackability" level of average people within this context, there is still room to go further in closing the "hackability" gap between the professional maker and the mass population.

REFERENCES

American, Bureau of Labour Statistics. (2016). CONSUMER EXPENDITURES--2015. Retrieved from https://www.bls.gov/news.release/cesan.nr0.htm

Ames, M. G., Bardzell, J., Bardzell, S., Lindtner, S., Mellis, D. A., & Rosner, D. K. (2014, April). Making cultures: empowerment, participation, and democracy-or not?. In CHI'14 Extended Abstracts on Human Factors in Computing Systems (pp. 1087-1092). ACM.

Buechley, L. (2014). Speech presented at Eyeo festival. Retrieved from https://vimeo.com/110616469

Briodagh, K. (2015, May 07). New Research Forecasts Growth of Connected Home Market. Retrieved from http://www.iotevolutionworld.com/smart-home/articles/403031-new-research-forecasts-growth-connected-home-market.htm

BI Intelligent. (2016, April 20). WeChat breaks 700 million monthly active users. Retrieved from http://www.businessinsider.com/wechat-breaks-700-million-monthly-active-users-2016-4)

Collins, L. (2015, March 10). Is the IKEA Aesthetic Comfy or Creepy? Retrieved from http://www.newyorker.com/magazine/2011/10/03/house-perfect

Digerfeldt-Månsson, T., & Venkatesh, A. (2005). Design As a State-of-Mind: The Aesthetics of Design and the Art of Marketing.Moore, G. A. (1998). Crossing the chasm. Chichester: Capstone.

Deuze, M. (2007). Convergence culture in the creative industries. International journal of cultural studies, 10(2), 243-263.

Doyle, R. B. (2015, February 09). Ikea designers find inspiration in 'home visits to real people' Retrieved from http://www.curbed.com/2015/2/9/9994148/ikeas-design-team-frequently-invites-itself-to-peoples-homes

Dahl, R. A. (1957). Decision-making in a democracy: The Supreme Court as a

national policy-maker. J. Pub. L., 6, 279.

Daniel, M. P., & Tversky, B. (2012). How to put things together. Cognitive processing, 13(4), 303-319.

Eyþórsdóttir, K. (2011). The Story of Scandinavian Design: Combining Function and Aesthetics.

Emling, S. (2013, August 02). Study shows Millennials are more forgetful than seniors. Retrieved from http://www.huffingtonpost.com/2013/08/02/millennial-forgetfulness_n_3695512.html

Flower, L., & Hayes, J. R. (1984). Images, plans, and prose: The representation of meaning in writing. Written communication, 1(1), 120-160.

Faulkner, C. (2015, November 17). What is NFC? Everything you need to know. Retrievd from http://www.techradar.com/news/phone-and-communications/what-is-nfc-and-why-is-it-in-your-phone-948410

Fukui, R., Sunakawa, T., Kousaka, S., Watanabe, M., Sato, T., & Shimosaka, M. (2013). TansuBot: A drawer-type storage system for supporting object search with contents' photos and usage histories. *IEEE International Conference on Intelligent Robots and Systems*, 2703–2709. https://doi.org/10.1109/IROS.2013.6696738

Greenough, J. (2015, September 28). Here's why the US smart home market is poised to take off. Retrieved from http://www.businessinsider.com/the-us-smart-home-market-report-adoption-forecasts-top-products-and-the-cost-and-fragmentation-problems-that-could-hinder-growth-2015-090

Gelber, S. M. (1997). Do-it-yourself: Constructing, repairing and maintaining domestic masculinity. American Quarterly, 49(1), 66-112.

Gregoire, C. (2013, December 11). How Technology Is Warping Your Memory. Retrieved from http://www.huffingtonpost.com/2013/12/11/technology-changes-memory_n_4414778.html

Ganesh, S., & Malhotra, R. (2014, September). Designing to scale: A human

centered approach to designing applications for the Internet of Things. In Advanced Computing and Communications (ADCOM), 2014 20th Annual International Conference on (pp. 26-28). IEEE.

Glushko, R. J. (2013). The discipline of organizing. Bulletin of the American Society for Information Science and Technology, 40(1), 21-27.

Goh, K. N., Chen, Y. Y., & Lin, E. S. (2011, January). Developing a smart wardrobe system. In Consumer Communications and Networking Conference (CCNC), 2011 IEEE (pp. 303-307). IEEE.

Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M. (2013). Internet of Things (IoT): A vision, architectural elements, and future directions. Future generation computer systems, 29(7), 1645-1660.

Higginbotham, S. (2015, August 19). 5 reasons why the 'smart home' is still stupid. Retrieved from http://fortune.com/2015/08/19/smart-home-stupid/

Hwang, A., Liu, M., Hoey, J., & Mihailidis, A. (2013). DIY smart home: narrowing the gap between users and technology.

Hamer, R. (2015, July 19). Why Ikea's sales are still booming. Retrieved from http://www.marketyze.com/2015/why-ikeas-sales-are-still-booming/

Ion, F. (2015, January 13). Tile review: Would you pay $25 a year to find your keys (maybe)? Retrieved from http://www.greenbot.com/article/2867072/tile-review-would-you-pay-25-a-year-to-find-your-keys-maybe.html

Deganutti, C. (2012). Primary Target Market IKEA'S Business. Retrieved from http://www.itcdeganutti.org/attivita/lingue/2012-13/IKEA.pdf

IDEO.org, (2015). The file Guide to Human-Centered Design. Retrieved from http://plusacumen.org/courses/hcd-for-social-innovation/

Johnson, E. (2016, December 09). The Real Cost of Your Shopping Habits. Retrieved from https://www.forbes.com/sites/emmajohnson/2015/01/15/the-real-cost-of-your-shopping-habits/#7b7bd4b31452

Leitner, G., Ahlström, D., & Hitz, M. (2007). Usability—key factor of future Smart Home systems. In Home informatics and telematics: ICT for the next billion (pp. 269-278). Springer US.

Lost something already today? Misplaced items cost us ten minutes a day. (2012, March 20). Retrieved from http://www.dailymail.co.uk/news/article-2117987/Lost-today-Misplaced-items-cost-minutes-day.html

Long, B. (2015, April 09). Fast Fashion and the Capsule Wardrobe. Retrieved from http://www.huffingtonpost.com/brita-long/fast-fashion-and-the-capsule-wardrobe_b_7025392.html

M. (2016, April 16). Now where did I put those keys? Retrieved from http://thediagonal.com/tag/neuroscience/

MacVean, M. (2014, March 21). For many people, gathering possessions is just the stuff of life. Retrieved from http://articles.latimes.com/2014/mar/21/health/la-he-keeping-stuff-20140322

Mail On Line. (2012, March 20). Lost something already today? Misplaced items cost us ten minutes a day. Retrieved from http://www.dailymail.co.uk/news/article-2117987/Lost-today-Misplaced-items-cost-minutes-day.html

McGinn, D. (2016, June 08). Being More Productive. Retrieved from https://hbr.org/2011/05/being-more-productive

Mellis, D. A., & Buechley, L. (2014). Do-it-yourself cellphones. Proceedings of the 32nd annual ACM conference on Human factors in computing systems - CHI '14. doi:10.1145/2556288.2557309

Mohr, J. J., Sengupta, S., & Slater, S. F. (2009). Marketing of high-technology products and innovations. Pearson Prentice Hall.

Mota, C. (2011, November). The rise of personal fabrication. In Proceedings of the 8th ACM conference on Creativity and cognition (pp. 279-288). ACM.

Moore, G. A. (2002). Crossing the chasm.

Muguira, L., Ruiz-de-Garibay, J., & Vazquez, J. I. (2009, September). Interacting with the digital world through RFID-powered gadgets. In Software, Telecommunications & Computer Networks, 2009. SoftCOM 2009. 17th International Conference on (pp. 85-89). IEEE.

Norman, D. (2008). Simplicity is not the answer. Interactions, septiembre-octubre,

15(5), 45-46.

Norton, M. I., Mochon, D., & Ariely, D. (2011). The 'IKEA effect': When labor leads to love.

NextMarket Insight. (n.d). The mass market smart home: Examining use cases to drive smart home adoption. Retrieved from http://wwwassets.s3.amazonaws.com/global/vivint.com/resources/tips/Formatted%20Copy%20%20Smart%20Home%20Use%20Cases%20For%20Mainstream%20Adoption%20FINAL%201.0%5B1%5D.pdf

Perlmutter, D. (2015, March 18). The smart home promise vs. reality. Retrieved from http://www.essence-grp.com/news-and-events/news/smart-home-promise-versus-reality

Peifeng, H., Yuzhe, C., Jingping, S., & Zhaomu, H. (2016, July). Smart wardrobe system based on Android platform. In Cloud Computing and Big Data Analysis (ICCCBDA), 2016 IEEE International Conference on (pp. 279-285). IEEE.

Pine, B. J., Victor, B., & Boynton, A. C. (1993). Making mass customization work. Harvard business review, 71(5), 108-11.

Rosner, D., & Bean, J. (2009). Learning from IKEA hacking. Proceedings of the 27th international conference on Human factors in computing systems - CHI 09. doi:10.1145/1518701.1518768

Roedl, D., Bardzell, S., & Bardzell, J. (2015). Sustainable Making? Balancing Optimism and Criticism in HCI Discourse. ACM Transactions on Computer-Human Interaction,22(3), 1-27. doi:10.1145/2699742

Rose, D. (2014). Enchanted objects design, human desire and the internet of things. New York, NY: Scribner.

Saeed, D., & Iqbal, R. (2015, December). NFC and Wi-Fi enabled smart clock for smart communication. In Open Source Systems & Technologies (ICOSST), 2015 International Conference on (pp. 30-35). IEEE.

Schiller, J. (2010). Cyber attacks & protection: civilization depends on Internet & email. CreateSpace.

Story, M. F., Mueller, J. L., & Mace, R. L. (1998). Case 3 / Principle Three Simple and Intuitive Use. *The Universal Design File: Designing for People of All Ages and Abilities.* (pp.100-101). Raleigh, NC: NC State University.

Svenonius, E. (2000). The Intellectual Foundation of Information Organization. The MIT Press. Retrieved from http://www.amazon.com/dp/0262512610.

Schmidt, A., Gellersen, H. W., & Merz, C. (2000, October). Enabling implicit human computer interaction: a wearable RFID-tag reader. In Wearable Computers, The Fourth International Symposium on (pp. 193-194). IEEE.

Sundmaeker, H., Guillemin, P., Friess, P., & Woelfflé, S. (2010). Vision and challenges for realising the Internet of Things. Cluster of European Research Projects on the Internet of Things, European Commision.

Tanenbaum, J. G., Williams, A. M., Desjardins, A., & Tanenbaum, K. (2013). Democratizing technology: pleasure, utility and expressiveness in {DIY} and maker practice. In Proceedings of the Conference on Human Factors in Computing Systems (pp. 2603–2612). Paris, France. doi:10.1145/2470654.2481360

Thaler, C. (2016, January 18). Here's What Clutter Does to Your Brain and How to Fix It. Retrieved March 10, 2017, from http://blog.paleohacks.com/heres-what-clutter-does-to-your-brain-and-how-to-fix-it/

The Internet of Things. (2016, February 17). Retrieved from https://www.priv.gc.ca/en/opc-actions-and-decisions/research/explore-privacy-research/2016/iot_201602/

Woo, J. B., & Lim, Y. K. (2015, September). User experience in do-it-yourself-style smart homes. In Proceedings of the 2015 ACM international joint conference on pervasive and ubiquitous computing (pp. 779-790). ACM.

Wolf, M., & McQuitty, S. (2011). Understanding the do-it-yourself consumer: DIY motivations and outcomes. AMS review, 1(3-4), 154-170.

Zhuang, J. (2015). Instructions on how to assemble a future IKEA: From "Democratic Design" to "Democratic Designers. Retrieved http://designresearch.sva.edu/apply/instructions-on-how-to-assemble-a-future-ikea-from-democratic-design-to-democratic-designers-by-justin-zhuang/

APPENDICIES
APPENDIX A: Glossary

Consumables
Consumables are goods used by individuals and businesses that must be replaced regularly because they can wear out or are used up. Generally, consumables include clothing, food and other daily-use items.

Early adopter and early major adopter
Everett M. Rogers proposes that adopters of any new innovation or idea can be categorized as innovators (2.5%), early adopters (13.5%), early majority (34%), late majority (34%) and laggards (16%). Moore, G. A. (2002) proposes a variation of the original life cycle in the book of Crossing the chasm that the most difficult step to surpass the chasm is to make the transition between visionaries (early adopters) and pragmatists (early majority), because compared with visionaries, pragmatists believe in evolutionary not revolutionary and are looking for productivity enhancement (Mohr, J. J., Sengupta, S., & Slater, S. F. 2014).

ISO 9241-210:2010
Provides requirements and recommendations for human-centered design principles and activities throughout the life cycle of computer-based interactive systems (Norma, 2010).

Near-field communication (NFC)
Is a set of communication protocols that enable two electronic devices, one of which is usually a portable device such as a smartphone, to establish communication by bringing them within 4 cm (1.6 in) of each.

Radio-frequency identification (RFID)
Uses electromagnetic fields to automatically identify and track tags attached to objects. The tags contain electronically stored information. Passive tags collect energy from a nearby RFID reader's interrogating radio waves.

APPENDIX B: Research Ethics Board Approval

December 01, 2016

Dr. Katherine Sellen
Faculty of Design
OCAD University

File No: 100852
Approval Date: December 01, 2016
Expiry Date: November 30, 2017

Dear Mrs. Ling Ding, Dr. Katherine Sellen, Dr. Adam Tindale,

The Research Ethics Board has reviewed your application titled 'DEMOCRATIZING DESIGN OF SMART FURNITURE AND HOUSEHOLD OBJECT'. Your application has been approved. You may begin the proposed research. This REB approval, dated December 01, 2016, is valid for one year less a day: November 30, 2017. Your REB number is: 2016-72.

Throughout the duration of this REB approval, all requests for modifications, renewals and serious adverse event reports are submitted via the Research Portal. To continue your proposed research beyond November 30, 2017, you must submit a Renewal Form before November 23, 2017. If your research ends before November 30, 2017, please submit a Final Report Form to close out REB approval monitoring efforts.

If you have any questions about the REB review & approval process, please contact the Christine Crisol Pineda, Manager, REB secretariat at [redacted] or [redacted]

If you encounter any issues when working in the Research Portal, please contact our system administrator via [redacted].

Sincerely,

Tony Kerr
Chair, Research Ethics Board

APPENDIX C: Online Questionnaire

Democratizing design of smart furniture

Have you ever imagined creating smart furniture on your own at an affordable price? This research project tries to figure out which furniture with enchantment design could help you DIY smart furniture by hacking IKEA. With the new interactive connection between furniture and household object, you could enjoy smart home technology in the affordable and accessible way. Your response and contribution will benefit the future of smart furniture design and bring technology closer to everyone.

Informed Consent
Participation in this study is voluntary. If you wish, you may decline to answer any questions or participate in any component of the study. Further, you may decide to withdraw from this study at any time, or to request withdrawal of your data prior to data analysis (3 days from the date of survey submitted), and you may do so without any penalty.

Any data pertaining to you as an individual participant will be kept confidential. Results of this study may be published in reports, professional and scholarly journals, students' theses, and/or presentations to conferences and colloquia. Survey results will be available by May.10th, 2017. You may request a copy of the final report by contacting the Researcher ([redacted]) through [redacted]

This study has been reviewed and received ethics clearance through the Research Ethics Board at OCAD University (file no. 1422). If you have any comments or concerns, please contact the Research Ethics Office through [redacted]

* Required

1. **Consent to Participate By indicating your consent, you are not waiving your legal rights or releasing the investigator(s) or involved institution (OCAD University) from their legal and professional responsibilities. With full knowledge of all foregoing, I agree, of my own free will, to participate in this study.** *
   - ☐ Yes
   - ☐ No

2. **Please select your gender?**
   - ☐ Male
   - ☐ Female
   - ☐ No identified

3. **Please select your age group**
   - ☐ 20-25
   - ☐ 26-30
   - ☐ 31-35
   - ☐ 36-40
   - ☐ Above 40
   - ☐ No identified

4. Which of the following living situations best describe your current living situations?

- [ ] Living with child/children
- [ ] Living alone
- [ ] Living Together (couple or house sharing)
- [ ] Other: _____

5. Do you have any pieces of IKEA furniture?

- [ ] Yes
- [ ] No
- [ ] Other:

6. Can you assemble IKEA furniture by yourself?

- [ ] Yes
- [ ] No
- [ ] Other: _____

7. How would you describe how difficult it is to assemble IKEA furniture when following the manual instructions?

- [ ] Pretty easy
- [ ] Middle difficulty
- [ ] Hard
- [ ] Depends
- [ ] Other:

8. Have you heard of the term "IKEA hacker"?

- [ ] Yes
- [ ] No
- [ ] Other: _____

9. Have you hacked (create a new function by replacing or regrouping the components) any IKEA furniture?

- [ ] Yes
- [ ] No
- [ ] Other: _____

10. Which scenario below is a familiar experience in your life?

Messy Kitchen by the kids

Forgetting where you put a small item

Don't know which cosmetic product has expired

Heating system broken in the winter

Expired food is still in the refrigerator

( ) Too many clothes and shoes and never know which one is new or not worn

( ) Dog or cat scratching the sofa

( ) Other:_____

11. In the given scenarios, which furniture would you want to make smarter to help you in that messy moment?

( ) Smart pillow which can warm when people hold it

( ) Smart container/drawer which can inform people what items are inside

( ) Smart tag which can inform people which food is expired

( ) Smart closet that can indicate which clothes are worn the most or the least

( ) Smart Shoe cabinet which can indicate which shoes are worn the most or the least

( ) Smart kitchen cabinet which can open only by adult or the designated person when there is some dangerous item inside

( ) Smart toy holder which can be locked when parent says "no"

( ) Smart sofa which can make an alert when the cat or dog is scratching it

( ) Other: _____

APPENDIX D: Interview Guideline

Final user testing interview

Informed Consent
Participation in this study is voluntary. If you wish, you may decline to answer any questions or participate in any component of the study. Further, you may decide to withdraw from this study at any time, or to request withdrawal of your data prior to data analysis (3 days from the date of survey submitted), and you may do so without any penalty.

Any data pertaining to you as an individual participant will be kept confidential. Results of this study may be published in reports, professional and scholarly journals, students' theses, and/or presentations to conferences and colloquia. Survey results will be available by May.10th, 2017. You may request a copy of the final report by contacting the Researcher ([redacted]) through [redacted]

This study has been reviewed and received ethics clearance through the Research Ethics Board at OCAD University (file no. 1422). If you have any comments or concerns, please contact the Research Ethics Office through [redacted]

1. Have you own any piece of smart home device at home?

- [ ] Yes
- [ ] No
- [ ] Other: _____

2. If not, what the reason would stop you to adopting smart home technology at home?

- ◯ Expensive
- ◯ Low usability
- ◯ Fragmentation (Devices work separately)
- ◯ High computer literacy required
- ◯ Low perceived value
- ◯ High cost of installation
- ◯ Other: _____

3. Have you tried to hack your IKEA furniture before?

- [ ] Yes
- [ ] No
- [ ] Other: _____

4. If not, what is the main barrier for you to hack them?

Check all that apply.

- [ ] Too hard
- [ ] No time
- [ ] Don't want to
- [ ] Other: .....

5. Do you think this smart furniture prototype is useful and meaningful in your daily life? To some degree, it will help to solve the mess at your home?

- [ ] Yes
- [ ] No
- [ ] Maybe
- [ ] Other:

6. **Do you think you can install this smart furniture kit by your own with simple tools and paper instruction like IKEA furniture construction**?

- ◯ Yes
- ◯ No
- ◯ Maybe
- ◯ Other: .....

7. How much money you are willing to pay to own this smart furniture kit?

- ◯ 10 CAD
- ◯ 20 CAD
- ◯ 30 CAD
- ◯ 50 CAD
- ◯ Other: .....

8. The project makes me feel……?

.....

.....

.....

.....

9. What elements do you think could be improved?

10. What limitations does this project have?

11. Do you have any additional feedback?

APPENDIX E: Datasheet for RDM8800

ITEAD STUDIO
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Tech Support: support@iteadstudio.com

RDM8800 NFC/RFID Module

Overview

RDM8800 card reader is a module based on PN532 chip customized for 13.56MHz NFC RFID card, compatible with RDM6300 interface, which can read data directly from the serial interface.

Unlike ordinary RFID modules, RDM8800 integrates LGT8FF8A chip, compatible with Arduino library, thus we can modify the firmware to suit our own needs. Itead Studio also released the source codes of RDM8800 firmware, and users can make secondary development based on it.

Specifications

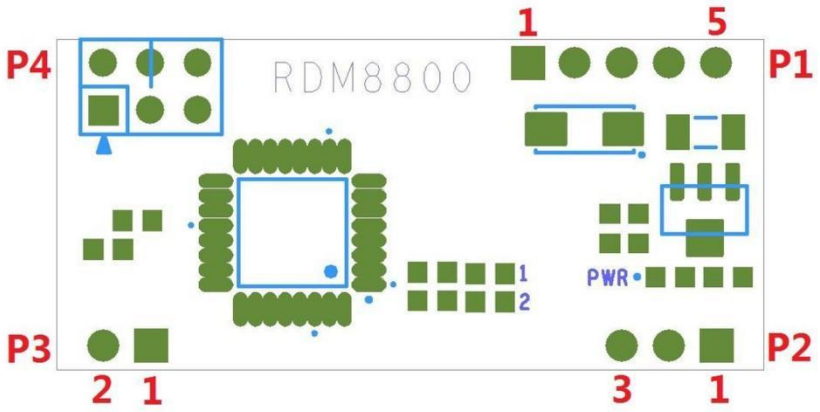
PCB size	38.1mm X 117.78mm X 1.6mm
Input voltage	5V
Interface	UART
Compatibility	With ISO 14443 Type A protocol With ISO 14443 Type B[1] protocol
Baud rate	9600

[1]: Version 1.0 firmware does not support ISO 14443 Type B at present, which requires users to make secondary development.

Electrical characteristics

Parameter	Min.	Typical	Max.	Unit
Supply voltage	4.8	5	5.5	VDC
Consumption current (average)	-	80	-	mA
Logic input voltage	Vss-0.3	3.3	5	VDC

Hardware



pinmap

Pin		Pin name	Description
P1	Pin1	+5V(DC)	Power input
	Pin2	GND	Ground
	Pin3	NC	Unoccupied

	Pin4	RX(TTL)	UART input
	Pin5	TX(TTL)	UART output
P2	Pin1	LED	Interrupt pin
	Pin2	+5V(DC)	Power output
	Pin3	GND	Ground
P3	Pin1	ANT1	Antenna interface
	Pin2	ANT2	
P4	Pin1	SWD	SWD debugging interface
	Pin2	3.3V	Power output
	Pin3	SWC	SWD debugging interface
	Pin4	NC	Unoccupied
	Pin5	RST	Reset
	Pin6	GND	Ground

Data formats

According to V1.0 firmware, there is one type of data output:

Directly output a card N.O.

The serial port will output a 10-digit decimal ACSII code card N.O. directly, which will be followed by a break line "0x0D 0x0A".

For example: the card number is 46553491, the output data will be "0046553491", (HEX: "0x30 0x30 0x34 0x36 0x35 0x35 0x33 0x34 0x39 0x31 0x0D 0x0A").

Interrupt pin

1. LED

   According to V1.0 firmware, once an ID N.O. is read, LED pin will output a 10ms high-level pulse.

Revision record

Version	Description	Written by	Date
v1.0	Initial edition	Stan Lee	10th, Dec., 2013