TAMPEREEN TEKNILLINEN YLIOPISTO
TAMPERE UNIVERSITY OF TECHNOLOGY

PATTHAMA HUNTONE

THE BENEFITS OF HAPTIC FEEDBACK IN MOBILE PHONE CAMERA

Master of Science thesis

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ABSTRACT

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Communication is basically the act of transferring information from one place to another. Feedback is a system where the reaction or response of the receiver arrives at the sender after he/she has interpreted the message. Feedback is inevitably essential to make two way communications effective. In fact, without feedback communication remains incomplete. At times, feedback could be verbal such as written and oral. Then in some cases, it could be nonverbal. Feedback is mainly a response from your audiences; it allows you to evaluate the effectiveness of your message. In fact research shows that the majority of the messages that have been sent are nonverbal and the ability to understand and use nonverbal communication is powerful tools that will help people connect with each other.

As well as communication where nonverbal shows much more impressive, a sense of touch as known as haptics plays an important role in our new phase of technology. It is the science of applying touch sensation and control to interaction with computer applications by using special input/output devices. It gives users a slight jolt of energy at the point of touch, providing instant sensory feedback, while reducing the audio, visual or audio-visual demand. Haptic technology is an evolutionary step into interacting with objects as an extension of our mind and allows for more socially appropriate and subtle interaction.

In this thesis, the benefits of haptic feedback in a mobile phone camera are explored and compared to the existing feedback mechanisms. Discovering expectations from users and gathering ideas in order to improve user experience in haptic feedback of a mobile phone camera will be the main focus as well as to understand "What make end users to use or not to use mobile phone camera?" and "What qualities of haptics could be used in the design of the user interface for mobile phone camera?". Depending on the settings and the quality of the mobile phones, the feedback from the camera can affect the user experience in many ways. I believe that to improve the existing feedback by applying haptic output such as a vibration or a vibrotactile signal may also considerably improve the user experience. Because haptic feedback is a new technology and proved to be efficient, to apply it to the mobile phone camera feedback should provide better support for users when compared to the existing feedback signals, which are audio and visual only.

One of the main objectives was to analyze the users' needs and expectations regarding the mobile phone camera haptic feedback and applications in various types of difficult situations and challenges users have encountered. Therefore, a user study was done at the beginning of the thesis work. Its aim was to get general results, which can be applied to haptic interaction on the mobile phone camera in order to improve existing applications and help easing users in their photo taking activities with their mobile phone camera. In addition, the results are considered to provide input for further studies as well as to offer concrete input to the development of a prototype.

PREFACE

Many years ago, I was a girl with a dream to see a country named “Finland” where I have read nothing but all good things, to name a few e.g. transparent government, free education, welfare state, high quality of life, and high quality of life for mom and babies. I was accepted in two university back then in Finland but I chose to study in Tampere University of Technology because Tampere seems a little bit warmer there than the other university’s location and I knew quite a few people who graduated from there whom in my opinion are very smart and talented.

I would like to thank University of Tampere for providing a course name “Haptic User Interface” by Prof. Roope Raisamo, which led me to my fascination about this technology and brought me to this thesis topic. I started this thesis in spring 2012; I went to Prof. Kaisa Väänanen and presented my idea that I would like to work on this type of topic. We took some time to finalize a topic that interested everyone. I know I took quite a very long time to finish it due to my health issues and life condition that happened which took me to too many dark places but for that I cannot use them as excuses. I have tried my best and I would say I try to have Finnish so called “SISU” and do my best to finish regardless of what has happened in life.

I would like to thank Tampere University of Technology to give me opportunity to do and finish my thesis. Million thanks to Prof. Kaisa Väänänen and Prof. Tommi Mikkonen for being so thoughtful, patient and kind. I would not have been able to finish my thesis without their guidance. Also many thanks to the police officers and police station for giving me chances time and time again to extend my student visa just so that I can finally finish my degree.

I would like to thank Sebastien Ermacora and Dr. Stefan Uhlmann for helping with their better academic English skill in proof reading my thesis for countless times. I would like to thank my friends from all around the world who made life in Finland brighter. And special thanks to Shriya my super nice roomie, Ionut and his love one who prove that a friend in need is a friend indeed, Ricardo, Bree, Tan, Alex, Defne, Marian and his beloved family for always bringing us joy, Ladear and Anca for always looking after me as a family and Puiu (Maruseki) for always taking us aurora hunting.

Finally, I would like to thank my family for their unconditional support and love. แม่ น้านี น้าดา น้องอูมทำสำเร็จแล้วนะคะ ขอโทษที่ต้องให้รอตั้งนานนะ ขอบคุณสำหรับทุกสิ่งทุกอย่างค่ะ

Tampere, 02.11.2016

Patthama Huntone

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LIST OF SYMBOLS AND ABBREVIATIONS

3D/3-D	Three-dimensional space
ALF-X	Advanced Laparoscopy through Force reflection
CAE	Canadian Aviation Electronics Ltd.
DSLR	Digital single-lens reflex camera
Eye-Rhas	Eye robot for haptically assisted surgery
GUI	Graphical User Interface
I/O	Input/Output
IT	Information Technology
Kinect	A motion sensing input devices by Microsoft
	PDA is mobile electronic device.
PDA	A Personal digital assistant or a personal data assistant.
PSmove	Handheld controller that works with the PlayStation Eye camera
RIO	Robotic Arm Interactive Orthopedic System
TELELAP ALF-X	A system offers a novel approach to remotely operated 3-dimension endoscopy by adding haptic sensation, an eye-tracking system, and a high degree of configuration versatility
TUI	Touch User Interface
VR	Virtual reality
WiiMote	Primary controller for Nintendo's Wii console

1. INTRODUCTION

This chapter presents background and motivation of this thesis. The goals and methodology are provided in sub-chapter 1.2. A short overview of the structure of this thesis is allocated at the end of this chapter.

1.1 Background and motivation

Communication is simply the act of transferring or interchange of ideas, opinion, or information by speech, writing, or signs from one place to another [1]. Even though this is a simple explanation, once we think about how we may communicate, the subject becomes a lot more complex. The communication process is complete once the receiver has understood the message of the sender. ***Feedback*** is an essential part of communication. It makes communication meaningful. It is an outcome of each interaction. It makes communication continuous. In the process of communication, the originator first obtains the message to be transferred and then select the method by choosing an appropriate channel or medium [2].

Based on the channels used for communicating, the process of communication can be broadly classified as verbal communication and ***nonverbal communication***. Verbal communication includes written and oral communication whereas nonverbal communication includes facial expressions, body movements and posture, gestures, eye contact, touch, space, voice, visuals diagrams or pictures used for communication. It means human being (or even animals) communicate with much more than words [3]–[7].

In fact research shows that the majority of the messages that have been sent are nonverbal and the ability to understand and use nonverbal communication is powerful tools that will help people connect with each other [6].

As well as communication where ***nonverbal*** shows much more impressive, a sense of touch as known as ***Haptics*** (pronounced *hăp'tĭk*, the word originates from the Greek word “haptikos” “haptesthai” meaning to grasp, to touch [8].) plays an important role in our new phase of technology. It is the science of applying touch sensation and control to interaction with computer applications by using special input/output devices. A touch sensation refers to a ***tactile feedback*** technology that takes advantage of a sense of touch by applying forces, vibrations or motions to the users. Users can receive feedback in the form of felt sensation on the hand or on other parts of the body [9].

The best example to present the use of haptic technology in daily life is the feedback that users get while they are pressing a touch screen on their smartphones, any other kind of other touch screens, or even a phone vibration is also included where users can physically feel their interface interactive via ***vibrotactile actuator***. It gives users a slight jolt of energy at the point of touch, providing ***instant sensory feedback***, while reducing the audio, visual or audio-visual demand[9], [10].

As previously introduced, ***haptic technology*** is an evolutionary step into interacting with objects as an extension of our mind and allows for more socially appropriate and subtle interaction.

Haptic technology has been applied to many different areas, for example, in mobile phone and smart phone market (e.g. force feedback touchscreens, vibrations, vibrotactile) [11], the game market (e.g. the force feedback joystick, the WiiMote, the PSmove and the Kinect) [9],[12], the medicine, medical and surgical (e.g. TELELAP ALF-X Endoscopic Robotic Surgical System, Eye-Rhas, RIO Robotic Arm System, CAE Endoscopy VR Surgical Simulator [13]–[15]), and in aeronautic and aerospace industries (e.g. the haptic virtual reality learning / training devices, teleoperation or telerobotics to present-day developments in VR and simulation) [16], [17].

In this thesis, the benefits of haptic feedback in a mobile phone camera are explored and compared to the existing feedbacks. Discovering expectations from users and gathering ideas in order to improve user experience in haptic feedback of a mobile phone camera will be the main focus.

Personal interests in camera, haptic feedback as well as background studies both in user experience and software development; lead to the choice of this topic. Being a regular user of mobile phone camera and disappointed by the existing feedback of the mobile phone camera motivates the necessity to improve the mobile phone camera feedback.

Depending on the settings and the quality of the mobile phones, the feedback from the camera can affect the user experience in many ways. Therefore to improve the existing feedback by applying haptic output such as a vibration or a vibrotactile signal may also considerably improve the users experience in most conditions.

Because haptic feedback is a new technology and proved to be efficient, to apply it to the mobile phone camera feedback should provide better support for users when compared to the existing feedback signals, which are audio and visual only.

1.2 Research goals and methodology

The main goals for this thesis are to study user experiences, design and provide ideas for further development of the haptic mobile phone camera user interface or TUI. The fundamental research questions for this thesis are as follows:

RQ1. What are the potential benefits of the haptic technology in mobile phone camera?

RQ2. What qualities of haptics could be used in the design of the user interface for mobile phone camera?

RQ3. What are the expectations from users that could utilize in the implementation phrase?

Research approach in this thesis is literature review and a user study based on semi-structured interviews and qualitative analysis of the user study data.

1.3 Structure of the thesis

Firstly, chapter 1 “Introduction” *presents background and motivation of this thesis.* Secondly, chapter 2 “Photo taking habits” *gives an insight of photo taking habits based on a literature review.* Thirdly, chapter 3 “Haptics in users interface” *gives an insight of haptics in users interface.* Later on in chapter 4 “A study of mobile phone camera usage habits and challenges” *presents the methodology used in the observational part of the thesis.* In chapter 5 “Results of the study of mobile phone camera usage habits and challenges” *presents the results of the interviews concerning mobile phone camera usage which is divided in four sub-chapters.* Lastly, in chapter 6 “Conclusions” *presents summary of the thesis.*

2. PHOTO TAKING HABITS

This chapter gives an insight of photo taking habits based on a literature review. First, I present a memorable phrase "A picture is worth a thousand words." to discover the journey of this notable phrase. Later, I explore the purpose of photography to uncover how photos and pictures have been engaging in our lives. Then, I present the history of photography. Finally, I describe the evolution of photography and photo taking habits, followed by a summary of the chapter 2.

2.1 A picture is worth a thousand words

"***A picture is worth a thousand words***" is a significant phrase of its time that subsequently has become a memorable phrase until the present day. The phrase had emerged in United States of America in the early part of the 20th century [18].

It is in fact a short expression but its meaning is very powerful. It contains a profound meaning and absolute truth that has been gradually integrated into our culture. Photos have been in our culture for ages because of their abilities. It is easier and faster to capture each scenario than explain them with words. It is more manageable to capture a very special moment and share with the loved ones who cannot be present at that certain period of time. It is one of the best ways to capture the memories and be able to relive those memories after sometime as if those moments just happened mere seconds ago. It will be very interesting to recall the earliest known uses of the phrase to better understand the history of pictures/photos and the origin of the expression.

The expression "*Use a picture. It is worth a thousand words*." is the first known references from a 1911 newspaper article quoting newspaper editor Arthur Brisbane discussing journalism and publicity. Later on in year 1913, a similar phrase, "*One Look is Worth A Thousand Words*", was used in a 1913 newspaper advertisement for the Piqua Auto Supply House of Piqua, Ohio. In 1918, the phrase "*One Picture is Worth a Thousand Words*" appeared in a 1918 newspaper advertisement for the San Antonio Light [19], [20].

However it is commonly acknowledged that the modern use of the phrase originates from an article by Fred R. Barnard in the advertising trade journal Printers' Ink, promoting the use of images in advertisements appearing on the sides of streetcars [21]. The December 8, 1921 issue carries an ad entitled, "*One Look is Worth a Thousand Words*" [22].

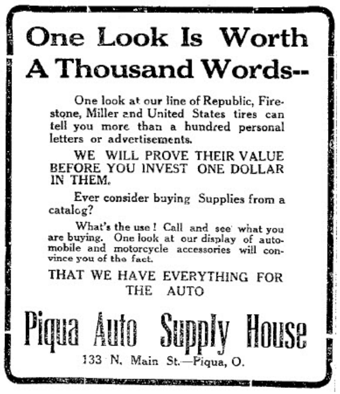

Figure 1. *1913 newspaper advertisement [22]*

These are only few examples that represent the origin of the expression that is now used worldwide. Nevertheless the history of photography is considerably longer than these previously mentioned phrases themselves. In the next sub-chapter, I will examine the purpose of photography to enhance our understanding towards photography. Furthermore successively in sub-chapter 2.3, the history of photography will be reviewed.

2.2 The purpose of photography

The prior saying "***A picture is worth a thousand words.***" is undoubtedly recognized by people worldwide. Several Medias such as TV, newspaper, magazine, and the Internet have used this phrase recurrently. Google Images, Flickr, Facebook, and Instagram are the good examples of picture-based sites that are flourishing and have become extremely popular. Psychological research supports the concept as well that we do remember pictures quicker than we do words [23]. Therefore, before exploring the history of photography in sub-chapter 2.3, understanding the reason of why we remember pictures better than words is thought-provoking.

> *"Humans have a remarkable ability to remember pictures. It was shown several decades ago that people can remember more than 2,000 pictures with at least 90% accuracy in recognition tests over a period of several days, even with short presentation times during learning. This excellent memory for pictures consistently exceeds our ability to remember words [24, p.2703]."*

Grady et al. [24] have studied human memory on the same suspicion whether recalling pictures are better than recalling words. They have examined human brains by observing the activity pattern in the brains during their experiments. The result has shown that superior general memory for pictures might be intervened by more compelling and automatic engagement of areas important for visual memory, including medial temporal cortex, while the mechanisms underlying specific encoding methodologies seem to work comparatively on pictures and words. The hypothesis proposed that pictures stimulate a more elaborate or associative encoding than happens with words [24].

Goolkasian and Foos [25] evaluate the specific cognitive requirements of handling and storing in working memory and inspected at exactly how effective the coordination had been when items for storage space differed in format/modality. These studies revealed that the method by which information is presented has an impact on working memory. After examination, they found that content that is presented, as printed words would be the least effective, pictures and spoken words may actually offer comparable results. [25].

Foos and Goolkasian [26] did experiments and have found that to remember the printed words, participants needed to put more effort and focus when compare to pictures and spoken words. Nevertheless in their studies, they believed that the exact mental process triggers short-term memory [23], [26].

Harper [27] use photographs in his research "Photo elicitation" during interviews. Harper did not use only text but also photographs. He introduced the photographs into the research interviews. The experiment was based on the theory of physical basis that the parts of the brain that process visual information are evolutionarily older than the parts that process verbal information. In the research, he mentioned that by exchanging only words exploit less capacity of the brain than when exchanging photographs. Therefore, using photographs stimulate our consciousness profounder than comparing to using only words [27].

> *"The central function of photographs has usually been to strengthen memories. Pictures have been seen as a tool for remembering [28, p.24]."*

Oates and Reder [29] also mention that traditional knowledge among many memory theorists also supports that pictures are better remembered than words on recognition tests. Paivio's Dual Code Theory [30] clarifies this fairly common phenomenon that when examining the pictures, they elicit their verbal label and, therefore, our memory preserved two representations or codes. On the other hand, words do not automatically elicit a picture, and thus they have a comparatively damaged memory representation. The redundant representation for pictures makes their recovery or recognition more plausible compared to stimuli studied as words see figure 2 to understand how human remember via each senses [29]

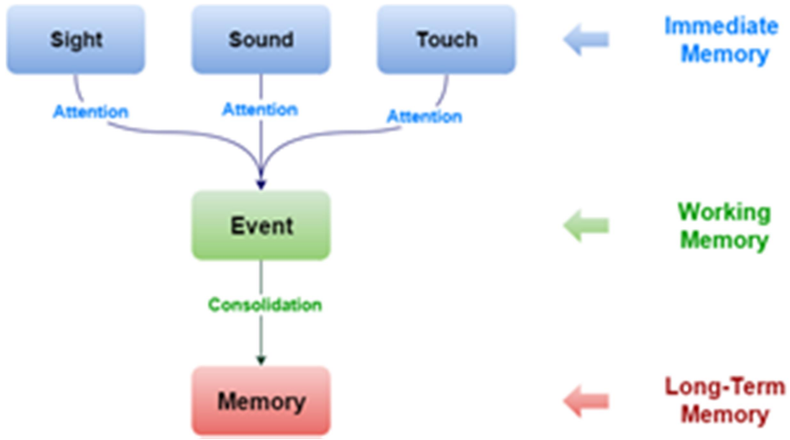

Figure 2. *How to remember when you see, hear or touch [31]*

From the aforementioned, we can acknowledge that our brain responds to pictures and photographs in a particular way. Furthermore, with the same amount of time, remembering pictures or photographs requires less effort and attention when compared to remembering words.

Lehmuskallio and Sarvas [32] state that studies performed since the pre-digital era have shown that snapshot photography (usually family photography) has 3 key roles, it serves to document important moment for the family, to help remember those moments but also as a way to express cultural membership (unifying the relations inside the family). The editing process of these photographs is also an important part of the key roles [32].

> *"The importance of everyday photographs has most often been attached to memory. Photographs have been seen as a means of remembering the past. Pictures are used to build both the collective and individual identity. They trigger memories that people use to redefine themselves [28, p.24]."*

After investigating one study by Van House et al in 2004, Gye [33] have mentioned one particular useful set of categories that could help us understand the purpose of photography. Gye [33] have categorized them into: constructing personal and group memory, creating and maintaining social relationships, and self-expression and self-presentation.

Gye [33] have explained that personal photographs not merely bind us to our very own pasts, they bind us to the pasts of those social groups to which we belong. Furthermore, by exchanging and sharing personal photographs is essential for the maintenance of relationships. One significant function of personal photography is the role it plays as an aid to storytelling. Sharing memories through the creation of narratives around them plays a fundamental role in the construction and maintenance of personal relationships.

Gye [33] believed that photographs we take might easily tell the world who we are. Assuming that our view of the world is unique and enthralling, our expression would vary from one another. Photography for self-presentation relates more to photographs people take to display themselves, their family, their friends, their possessions, their pets and so on.

In conclusion, it is understandable that we have used pictures and photographs to ease remembering in various ways. We found that in limited time, it takes less effort and attention to remember pictures and photographs in comparison with words. In addition to that, studies have found many interesting theories of the reasons why we are taking photos, specifically to aid keeping the memories, to construct personal and group memory, to help maintaining ourselves in social relationships, and to support self-expression and self-presentation.

2.3 The history of photography

The term ***"Photography"*** was first used by Sir John Herschel in 1839, which was the year that the photographic techniques became public. The word is originated from the Greek words for light and writing. Nonetheless, the innovations which had led to photography development existed a long time before the first photograph itself [34].

It had been discovered as far back as the fifth century BC that an image of the exterior scene was created by sunlight shining through a small hole into a darkened room [35].

This is when the phrase ***"Camera Obscura"*** obtained its recognition. The phrase means "Darkened Room" [35] (Latin, literally interpreting to "dark room" [34]). The camera obscura had developed into a device that used a lens or a pinhole to project images upside down on viewing surfaces by ancient Greeks and Chinese [36]. In the year 1544, this camera ended up being used by Reiners Gemma Frisius, a mathematician, for observing a solar eclipse followed by Giovanni Batista della Porta who suggested this device as a drawing aid fourteen years later in 1558 [36].

The camera obscura had been around for at least four hundred years. However its use was restricted to its purpose as a support to drawing. The oldest record of the uses of a camera obscura can be discovered in the writings of Leonardo da Vinci (1452-1519), who may have used it as a support to understanding perspective [34].

In the 17th and 18th centuries, a table-top model was developed. By including a focused lens and a mirror, it was possible for a person outside of the box to find the image which was reflected through it see figure 3 [34].

Figure 3. *Camera Obscura in action* [37]

Even though the term ***"Photography"*** was first used in 1839 by Sir John Herschel, the first production of photograph was actually in 1925-1927 by a French man named Joseph Nicéphore Niépce. He used chemicals on a metal plate, positioned inside of a camera obscura; he managed to capture an obscure image of the view outside of his window. He called his process "***heliography"*** (after the Greek "of the sun") [34].

Figure 4. *Nicephore Niepce, World's First Photograph 1827* [34]

The image in figure 4 is hard to decipher. The exposure lasted eight hours in order to let the sun move from east to west. Therefore, the sunlight could shine on both sides of the building. Another issue was the difficulty upon "fixing" the image so that it would not continue to darken when exposed to light [34].

Louis Daguerre is the most renowned of many people who created one of the most effective and commercially suitable forms of photography. He commonly used a camera obscura as an aid to painting in perspective. It had driven him to find a way to freeze the image. In January 1829, he joined his partnership with Niepce, after he had learned about his work in 1826. Unfortunately the partnership did not last long because Niepce died in 1833. However Daguerre persisted in his experiment [34].

Finally, Louis Daguerre was capable to minimize the exposure time to thirty minutes. Then later on in 1837, he discovered a chemical process that would fix the image permanently. He called this new procedure ***"Daguerreotype"***. Nonetheless, there were disadvantages of this new process, which included the fact that the length of the exposure time eradicated portraiture. The image was laterally reversed, and the image was very delicate. The other disadvantage was that it was a "once only" system since it was fixed to metal see figure 5 [34].

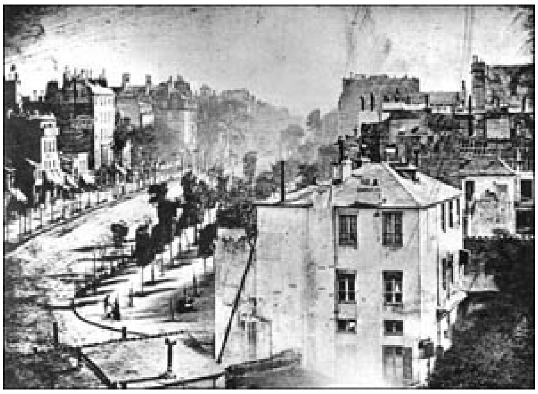

Figure 5. *Louis Jacques Mande Daguerre, Paris Boulevard 1839* [34]

Later on William Henry Fox Talbot made his attempt called ***"Calotype"*** (Greek, kalos means beautiful + -type [38]) where an image was produced on paper treated with silver iodide and developed by sodium thiosulphite [39]. This process was patented by him in 1841, in which a paper negative is produced and then used to make a positive contact print in sunlight [38].

In 1855, collodian dry plates were available. Shortly after a launch of gelatin dry plate, Richard Leach Maddox presented a challenging competition to quality and speed of the wet plates. This healthy competition leaded to create a better device, which further on gave birth to cameras small enough to fit in hands. Also the lower exposure times made candid photography eventually viable [36].

In 1884, George Eastman introduced flexible film, enabling several images to be developed on light-sensitized paper [34]. In 1888, he announced the "Kodak". It was a simple box camera with a single shutter speed and fixed focus lens [40]. Photography had reached a great deal of people. With his slogan *"You press the button, we do the rest"* he certainly brought photography to the public [34].

> *"With that step were established conditions for a continually accelerated pace of development which for a long time prevented any look backward. And so the his-*

torical or perhaps philosophical questions which accompany the rise and fall of photography for decades went unconsidered [41,p.5].”

From the camera obscura, we could notice that cameras have advanced and continued to transform through various generations of photographic technology, these include heliography, daguerreotypes, calotypes, dry plates, wet plates, film, and digital cameras as we all accustomed to nowadays.

2.4 The evolution of photography

“Taking photographs seems no longer primarily an act of memory intended to safeguard a family's pictorial heritage, but is increasingly becoming a tool for an individual's identity formation and communication. Digital cameras, camera phones, photo blogs and other multipurpose devices are used to promote the use of images as the preferred idiom of a new generation of users [42, p.57].”

Photography occurs to be immensely effective as a consumer technology since its introduction by Kodak within the late nineteenth century. The transformation to digital technologies has elevated the utilization of and enthusiasm for both photographic activity and passion on the part of photographers, viewers and subjects [43]. Throughout history of photography, we have witnessed digital photography effortlessly succeeded film photography [44]. Evidently, forms of cameras have without a doubt evolved over time starting from the first known design of a camera to digital cameras we recognize today. Especially, the purposes of photography have altered all the way through from supporting artists during painting to safeguarding memories. And up to these present days where photography has become a part of our daily life.

In particular, digital photography has transformed the photography world nearly entirely. Taking photo is no longer an act that demands plenty of equipment. Films are basically not needed anymore unless photographers intend to take photos with antique cameras to produce vintage style of photos. Digital photography makes photography easier, faster, cheaper and even better than before.

In 2003, Rodden and Wood provided and discussed the findings of a study that investigated exactly how individuals manage their collections of digital photographs. The six-month, 13-participant research included interviews, questionnaires, and analysis of use statistics gathered from an instrumented digital photograph management tool called Shoebox. Alongside simple searching features such as files, thumbnails and timelines, Shoebox provided advanced multimedia features such as content- based image retrieval and sound annotations. Their results showed that participants found their electronic pictures easier to handle than their non-digital ones mainly due to the simple browsing features. These outcomes should help the design of improved tools for managing digital personal photographs and collections [45].

Nevertheless, ever since mobile phone camera was introduced, it is undeniable that the worldwide popularity of the mobile phones along with their extra functionalities such as text messengers and picture taking devices using integrated camera, has increasingly changed the way users interact with their phones [33][46]. A mobile phone is no longer the mere device for calling, but it is now a smartphone, which is able to perform so many different tasks [33].

The quality of camera and new data plans developed for mobile phone lead users to take more pictures in a brand new way. Since mobile phone has become one of the necessary tools in our daily life, taking photo with a phone camera has become significantly simpler. For personal photography, mobile phone cameras have slowly replaced standalone digital camera due to their continuous presence in the life of users [44]. We have seen its feature to yet again excelled the standalone digital cameras in many of their functions [44].

By integrating digital photography with mobile phone, it is inarguable that we have arrived at the era where capturing any significant memories are effortless. It is simply involved taking your mobile phone out of your pocket and snapping a shot of each moment user desire. We have progressed thus far from the first known camera to the mobile phone cameras we recognize today.

2.5 New photo taking habits with mobile phone camera

> *"The convergence of the camera and mobile phone has proved to be highly popular. This should come as no surprise to anyone interested in both the history of mobility and the history of photography [33,p.279] ."*

In 2005, House et al. [47] declared that developments in networked electronic imaging vow to significantly affect the near-universal reference to photography that is specific. Creating technology for image capture and sharing requires knowledge of exactly how individuals use photos as well as the method they adapt increasing technology using their methods which can be photographic together with other way around. In their paper, they reported on that by reducing most of the barriers to camera phone usage and image sharing (including increasing image quality, reducing the sharing procedure, and removing cost barriers), they have discovered that users quickly develop new uses for imaging. Their innovative communicative uses of imaging are understandable with regards to the social uses identified from previous photographic activity as well as developing brand new functional uses [47].

In 2007, Gye [33]described that mobile camera phones are not just another type or sort of digital camera that can be found with us wherever we go. Camera phones are both extending existing personal imaging practices and allowing for the evolution of new kinds of imaging practices. Offered the centrality of personal photography to procedures of identification formation and memorialization, modifications to the ways people capture, store, and disseminate photographs that are personal, the employment of products like digital camera phones may have important repercussions for exactly how we realize whom we are and exactly how we keep in mind about our past [33].

Later in 2007, Ahern et al. [48] explained that as sharing individual news online gets easier and commonly spread, new privacy concerns emerge – particularly when the persistent nature associated with the media and associated context reveals details about the physical and social context by which the news items had been developed. They normally use context-aware camera phone devices to look at privacy choices in mobile and photo sharing online. Through data analysis privacy choices and associated context data from a real-world system, they identify relationships between location of photo capture and photo privacy settings. Further, they investigated through a collection of interviews with 15 users, which revealed common themes in privacy factors: protection, social disclosure, identity and convenience. Finally, they highlighted implications and opportunities for design of media sharing applications, including making use of past privacy habits to stop oversights and errors [48].

In the same year in 2007, Miller and Edward [49] presented initial findings from a research of photo-sharing site Flickr.com. In specific, they argued that Flickr.com generally seems to support a group that is different of techniques, socialization styles, and views on privacy. Further, through their examination of digital photo work activities of photographers—organizing, finding, sharing and receiving—they suggested that privacy issues and not integration that is enough existing communication stations have actually the potential to stop the 'Kodak Culture' from completely adopting current photo-sharing solutions [49].

In 2007, Ames and Mor [50] raised a question "Why do people tag?". They have found that users have mostly avoided annotating media such as photos – both in desktop and mobile surroundings – despite the countless potential uses for annotations, including recall and retrieval. They investigated the incentives for annotation in Flickr, and ZoneTag, a camera phone picture capture and annotation tool that uploads pictures to Flickr. In Flickr, annotation (as textual tags) serves both individual and social purposes, increasing incentives for tagging. On the other hand, ZoneTag, helps to tag camera phone photos that are uploaded to Flickr by permitting annotation and suggesting tags that are relevant after capture. Ames and Mor study of ZoneTag/Flickr users exposed various tagging patterns and emerging motivations for photo annotation. Their findings suggested implications for the design of digital photo organization and sharing applications [50].

In 2009, Lasén and Edgar [51] mentioned that portrait digital photography is causing the renegotiation associated with general public and private divided towards the transformation of privacy and intimacy, especially because of the convergence of digital camera models, mobiles, and Internet sites. This convergence plays a role in the re-definition of general public and private and also to the change of the boundaries, that have for ages been at the mercy of historical and change that is geographical. Taking photos or shooting videos of strangers in public places and showing them in webs like Flickr or YouTube, or making self-portraits offered to strangers in instant messenger, online networks, or photo blog sites are becoming a present trend for an increasing number of Internet users. Both are samples of the intertwining of on the internet and offline techniques, experiences, and meanings that challenge the original concepts associated with the public while the private uses of digital pictures are likely involved in the real way individuals perform being a stranger plus in the direction they relate with strangers, online and offline [51].

In 2010, Jankowski et al. [52] presented a geo-visual analytics approach to discovering individuals' preferences for landmarks and motion patterns from pictures published regarding the Flickr Internet site. The outcomes of analysis when it comes to Seattle area that is metropolitan to differentiate between internet sites which are sometimes popular among the photographers and can be looked at as potential tourist attractions from web sites that are frequently visited and already called town landmarks. The analysis of motions of photographers over the area that is metropolitan is that most itineraries of photographers are short and very localized [52].

In the same year in 2010, Lane et al. [53] stated that significantly, smartphones these days are programmable and include a growing group of cheap effective embedded sensors, for instance an accelerometer, electronic compass, gyro-scope, GPS, microphone, and camera, which are enabling the emergence of individual, team, and community scale sensing applications. They believed that sensor-equipped mobile phones will revolutionize numerous sectors of our economy, including business, health care, social networks, environmental monitoring, and transport [53].

In 2012, Häkkilä et al. [54] reported research that investigates motivations and techniques in taking pictures for functional purposes. Their findings exposed that users have a common factor and broadly adopted techniques where camera phones are utilized for functional photography. Major cases include taking pictures as a memory aid or even to secure proof. The capacity to just take photos with or without preparation may be the key reason behind this practice. Their information showed that use cases are distributed over a large number of domains and so are entwined with everyday tasks of users [54].

In 2013, Lee et al. [55] revealed that an incredible number of geo-tagged photos have become available as a result of extensive of photo-sharing sites. These social medias capture appealing points-of-interest and contain photo-taking that is fascinating. Wide range of that user-oriented information produces brand new challenges and understanding of photo-taking behavior of people is important for tourism-related companies. Lee et al. analyzed geo-tagged photos from Flickr for Queensland, a tourism-intensive as well as the second state that is largest in Australia. They reported interesting points-of-interest patterns and discuss these findings [55].

In 2015, Vill [56] explained that an image can mediate the clear presence of the absent, the object or individual captured in the photograph. Now, with all the aid of the network connection provided by the camera phone, photographs can function as communicative things through which distant people engage with each other quite synchronously, helping them to form a connection in the present, in contrast to a connection between past and present. The reason of the content would be to join these two facets of existence, therefore integrating the study of photography with mobile communication studies. The article plays a role in the discussion on camera phone photography by focusing expressly on photography as a communication medium. The camera phone deserves a position that is substantial the study of photography, as a rapidly increasing share of cameras are placed in mobile phones. Into the article, it really is argued that mediating existence visually is an integral training of making use of photographs in mobile interaction. With results from an empirical case study of Finnish camera phone users, Vill demonstrated how photographs can offer means for both maintaining a link between individuals and mediating presence [56].

In 2016, McNabb and Gray [57] reported that in their previous research on smart phone usage while driving has mainly centered on phone calls and texting. Drivers are now increasingly using their phone for other tasks during driving, in particular social media that have actually different cognitive needs. The current study contrasted the outcome of four different cell phone tasks on car-following performance in a simulator. Phone tasks were chosen that vary across two facets: interaction medium (text vs image) and task pacing (self-paced vs experimenter-paced) and the next: Text messaging with the experimenter (text/other-paced), reading Facebook articles (text/ self-paced), exchanging photos along with the experimenter via Snapchat (image, experimenter -paced), and viewing updates on Instagram (image, experimenter -paced). As a baseline (standard), drivers also performed driving without any distraction. Results showed that brake response times (BRTs) were significantly greater in to the conditions, which are text-based when compared with both the conditions that are image-based as well as the standard. They could not find significant differences for BRTs in the image-based and baseline conditions as well as no significant impact of task-pacing. Comparable results were acquired for Time Headway variability. These responses are constant with all the image superiority impact found in memory claim and research that image-based interfaces could offer safer ways to “stay connected” while driving than text-based interfaces [57].

> *“The development of smartphone technology has enabled the transmission and sharing of captured images to be fast, cost-effective, and efficient. Although smartphones are used to take clinical photographs in many oral and maxillofacial surgery (OMFS) departments and in other visually oriented specialties,*

> *many clinicians seem to be unaware of the policies that regulate the photography of patients on personal electronic devices [58,p.104]."*

In conclusion, we have seen many new habits arising along the way with mobile phone camera development for example sharing, posting, and tagging photos. However, in the end after over exposure, people are yearning for privacy settings where they could only share their photos and memories merely with their close ones. On the other hand, there are still a lot of people who do not regard sharing with the whole world as challenging. Therefore, with the new technology in the mobile phone camera, which is going to provide even better quality of photos, people might over share their photos.

2.6 Summary

Without a doubt taking photos has grown viral and became a hobby or even a career once cameras had become famous for the public. There are always many types of photographer such as immature photographers who take photo with their digital camera or their mobile phone camera or professional photographers with their DSLR camera and other gadgets such as wide range of lenses and flash to use in different situation. And there are those who are taking photo as a habit with their mobile phone camera, for example taking photo of food, often take selfies, taking photos of all activities they are doing all day, now especially with the social media such as Facebook, Instagram, and SnapChat becoming increasingly popular. People are now getting used to share their lives online, taking photos and just post and share sometimes without second thoughts.

Therefore, people should have their right priority and consider their safety as their first priority while sharing photos to the whole world.

In the end, we all need to be cautious. We should not get obsessed over a new technology so that technology becomes our boss instead of vice versa for the reason that in the end, they are here to ease our lives not the other way around. We should always remember the true purpose of it. We are obligated to always take responsibility for our own actions e.g. when you are sharing photos, have you ever asked for their consents to publish or share them with others.

Another immense concern is a photo shaming which has been one of the worst problems among this generation. This is another vast concern we must look into and try to find a way to help young and new generation to love who they are and be proud for who they are from inside because everything is not what it seemed to be e.g. models or celebrities can be edited by program Photoshop.

3. HAPTICS IN USERS INTERFACE

Chapter 3 gives an insight of haptics in users interface. First, I introduce a world of sensation and perception in order to understand the important of a sense of touch compared to other senses and portray its relation to haptic perception. Then I concentrate on haptics technology in mobile phone that is relevant to this thesis.

3.1 A world of sensation and perception

> *"Why do we have sense-organs? We have ears, intricate structures composed of membranes, bones, channels, etc., a nose with two nostrils and a mucous membrane which covers a nasal cavity. We have taste buds, a range of tactile sensors under our skin, not to mention the eyes. Why? The simple answer is that we have sense-organs because they enable us to perceive [59, p.1]."*

Our senses permit us to discover the world we live in, and are one of the essential elements of consciousness. Their significance can effortlessly be viewed from many inventions that have been built upon each sense. For example, radio is associated with hearing, cooking with taste and smell, and television with both vision and hearing [60].

Fascinatingly, it is known in branding research that brand experiences are associated with human senses namely sight, sound, touch, smell, and taste. It has been found that sensory experiences are a significant part regarding the entire brand experience. A higher quality sensory experience that entertains and stimulates consumers is considered a vital factor that can differentiate one brand experience from another. Furthermore, it has been proven to determine an increased level of customer satisfaction. This is a reason why the world most successful firms make an effort to distinguish their brands by attracting to five senses of consumers to produce competitive benefit. For instance, Starbucks employs sensory advertising by providing a pleasing interior and lighting, relaxing music, the smell and taste of freshly ground coffee, and comfortable armchairs [61].

> *"Humans are the product of biological and cultural adaptation to our planet achieved in the process of human evolution [62, p.1]."*

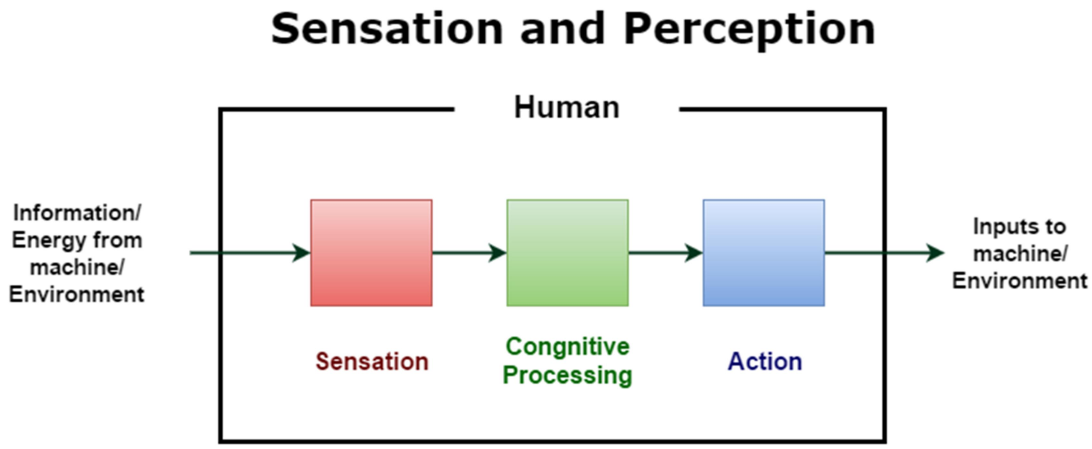

Figure 6. *Human characteristics sensation and perception quick review* [63]

The concept of five fundamental human senses is commonly traced back to De Anima book (On the Soul) by Aristotle, in which he dedicates a separate chapter to vision, hearing, touch, smell and taste. He defined five exteroceptive senses that allow humans to perceive the outside world [64], [65]. Figure 6 shows an overview about the human characteristics sensation and perception.

Senses are physiological capacities of organisms that provide data for perception. The nervous system has a distinct sensory system or organ, dedicated to each sense. Humans have a variety of senses. The five traditionally recognized senses are sight (ophthalmoception), hearing (audioception), taste (gustaoception), smell (olfacoception or olfacception), and touch (tactioception) [66].

An alternative approach to categorizing sensory is based on the type of stimulus that is measured, resulting in the differentiation between chemosensation, thermosensation, photosensation, and mechanosensation. Whilst sight (photosensation), hearing and balance (mechanosensation), and smell (chemosensation) effortlessly fit into these four functional classifications, the circumstances are more complex for the two other exteroceptive senses. Taste is primarily classified under chemosensation, but has some clear thermo- and also mechanosensitive aspects; touch involves a combination of thermo- and mechanosensation [65].

The sense organs namely eyes, ears, tongue, skin, and nose, serve to protect the body. The human sense organs consist of receptors that exchange information through sensory neurons to the proper places within the nervous system. Each sense organ consists of different receptors [67].

- General receptors are spotted throughout the body simply because they exist in skin, visceral organs (in the abdominal cavity), muscles, and joints [67].

- Special receptors include chemoreceptors (chemical receptors) in the mouth and nose, photoreceptors (light receptors) in the eyes, and mechanoreceptors in the ears [67].

Each individual of the five senses comprises of organs with specific cellular structures that have receptors for certain stimuli. These cells have connections to the nervous system and therefore to the brain. Sensing is completed at primitive levels in the cells and integrated into sensations in the nervous system [68].

> *"Sight, sound and the body in general have been studied extensively in the humanities, the social sciences and the natural sciences. But within an academic climate that celebrates visual cultures, and the popular media's infatuation with visuality, touch remains largely neglected, forgotten [69, p.1]."*

3.2 The sense of Touch

> *"And I found that of all the senses the eye was the most superficial, the ear the most haughty, smell the most voluptuous, taste the most superstitious and inconstant, touch the most profound and philosophical [69, p.1]."*

In order to acknowledge the essences of touch from the other senses, the sensory homunculus is shown below in Figure 7. It exhibits what the body of a man would seem like if each part grew in proportion to the area of the cortex of the brain concerned with its sensory perception [70].

Figure 7. *The sensory homunculus from the British Museum Of Natural History* [70]

As for the cortical homunculus, it is a physical representation of the human body that is located within the brain. A cortical homunculus is a neurological "map" of the anatomical divisions of the body. There are two types of cortical homunculus; sensory and motor [71]. In this chapter we will focus only on the sensory homunculus.

The sensory homunculus is a bodily interpretation of the somatosensory cortex. The term homunculus is originated from the Latin word "little man" and in psychology is known as the "little man inside your brain". A homunculus has oversize lips, hands, feet, and tongue with thin arms and legs. The somatosensory cortex is located within the parietal lobe behind the frontal cortex where it processes touch sensory information. The body of homunculus is scaled in accordance with the quantity of cortex it is dedicated to it. As an example, the large hands of homunculus symbolizes an intensive proportion of ***touch receptors*** within the somatosensory cortex, *indicates that our hands are a lot more sensitive to touch than the rest of the body* [72].

The sense of touch in fact comprises of the perception of several distinct types of stimuli, including temperature, position, and pressure. Correspondingly, electrophysiologists have comprehended that recognition of touch is executed by neurons of restricted specificity, in a way that painful (or noxious) stimuli can activate neurons of a different class than nonnoxious pressure [73].

Schuwerk et al. [74] state that "early studies about the ability to touch and physically interact with objects in a virtual environment have shown that haptic feedback mediated through specialized haptic interfaces leads to an increased sense of immersion and improved task performance. It also leads to an increased sense of togetherness, if more than one user is involved in a so called shared haptic virtual environment [74] [60, p.5:2]."

The term "haptics" refers to sensing and manipulation through the sense of touch. Although the word haptics might be new to many individuals, it is likely that majority have been already utilizing haptic interfaces (for instance, your keyboard and mouse). The haptic system is bidirectional unlike vision and audition that are mainly input systems for the human observer. Numerous activities, for instance the reading of Braille text by the blind, need the utilization of both the sensing and manipulation aspects of the haptic system [75].

"The human haptic system consists of the entire sensory, motor and cognitive components of the body-brain system. It is therefore closest to the understood meaning of proprioceptive (see Figure 8) [76, p.2]." *"Haptics is now commonly viewed as a perceptual system, mediated by two afferent subsystems, cutaneous and kinesthetic, that most typically involves active manual exploration [77, p.1439]."*

Term	Definition
Haptic	Relating to the sense of touch.
Proprioceptive	Relating to sensory information about the state of the body (including cutaneous, kinesthetic, and vestibular sensations).
Vestibular	Pertaining to the perception of head position, acceleration, and deceleration.
Kinesthetic	Meaning the feeling of motion. Relating to sensations originating in muscles, tendons and joints.
Cutaneous	Pertaining to the skin itself or the skin as a sense organ. Includes sensation of pressure, temperature, and pain.
Tactile	Pertaining to the cutaneous sense but more specifically the sensation of pressure rather than temperature or pain.
Force Feedback	Relating to the mechanical production of information sensed by the human kinesthetic system.

Figure 8. *Definitions of main terms used when describing haptics and the sense of touch [76, p.2]*

In figure 8 shows definitions of main terms used when describing haptics and the sense of touch.

Lederman and Klatzky [77] explain that cutaneous receptors are discovered across the body surface, underneath both hairy and hairless skin. Thus far, the majority of human scientific studies have concentrated on mechanoreceptors and thermoreceptors found within the hairless ("glabrous") skin of the human hand. The two further peripheral receptor populations known as thermoreceptors respond to increase or decrease in skin temperature, and mediate the human experiences of warmth and cold, correspondingly [77].

The kinesthetic retrieves input from mechanoreceptors in muscles, ligaments, and joints contribute to the human perception of limb position and limb movement in space. Study in the motor-control area is likely to treat feedback that is kinesthetic as sensory signals to be incorporated in models (feedback, feedforward) of limb movement and grasping. Therefore, we will consider the contributions of kinesthesis and kinesthetic inputs only where they are inextricably bound up with human haptic processing and representation that is, for purposes of sensing, perceiving, and thinking about objects, their properties, and the space within which they occupy. Cutaneous and kinesthetic inputs are combined and weighted in different ways to serve various functions that are haptic [77].

Gentaz et al. [78] depict that ***Haptic perception*** permits us, for instance, to acknowledge an object, or one of its qualities like its size, shape or weight, the position of its handle or the materials. A basic property of the haptic system is that it relies upon touch. The "tactile perceptual field" (i.e., the portion of the skin that is in contact with the external stimulus) has a restricted size (i.e., the surface of both hands at maximum) and a restricted reach (the length of the arm) [78]. *"It results from these characteristics of the tactile perceptual field that the perception of the spatial properties of the objects typi-*

cally involves some displacements of the arm and the hand to explore the stimulus. In fact, it is also acknowledged that the nature of these exploratory movements frequently varies, depends upon the specific property regarding the object that is touched [78, p.331].”

For instance, one might trace the curve of an object with one finger to recognize its shape or squeeze it with the whole hand to recognize its conformation. Moreover, the haptic system must integrate information about the parts of the body touching the object with information about the position of the body parts in space. It results from these properties of the haptic system that the haptic perception of space is far removed from the proximal stimulation that occurs during the manual exploration, and depends on spatio-temporal integration of the kinesthetics and tactile inputs to build a representation of the stimulus [78].

> *“Man, through the use of his hands, as they are energized by mind and will, can influence the state of his own health [79, p.92].”*

“Mary Reilly’s aforementioned words remind us of the significant role one’s hands have in occupation and health. The ability to reach out touches, and grasp objects, people, and materials in the natural and built world allow people to explore, maneuver, develop skills, and interact with their environment in ways that contribute to their occupational performance, their sense of meaning, and the development of their identity [80] [66, p.104] ” stated by Black in her Journal of Hand Therapy.

In summary, we have discovered that when discussing about **‘Haptic’**, we are referring to information processing perceptual system which uses inputs from receptors embedded in the skin, also in muscles, tendons, and joints. The different sensory input patterns manufactured as individuals move their hands over an object during perceptual exploration and manipulation, notifying us about its properties - for instance, that it is smooth, hard, cold, round, and weighs very little [81]. Additionally, we have learned that when mentioning about **‘Haptics’**, it indicates *“a feedback technology that takes advantage of the human sense of touch by applying forces, vibrations, and/or motions to a haptic-enabled user device such as a mobile phone [82, p.11].”*

> *“Touch is unique among the senses because it allows simultaneous exploration and manipulation of an environment [83, p.146].”*

As we can see from the previous sub-chapter 3.1 and this sub-chapter 3.2 that without our senses the way we live and perceive the world around us would be entirely different. We would have been most likely unable to understand things around us nor learning any new things. There would have been ‘zero’ innovation. We might appear to be completely deserted. This might be the explanation to why there have been numerous studies related to senses in various aspects. I believe one of the primary purposes is to improve our understanding towards human senses and to have the potential to develop innovative items for instance the “Braille text” that can help blind people. The sense of touch, as known by the term “Haptic” is an example. Despite the fact that the studies in “The Sense of Touch” might be the newest among all senses, but there have been plenty of interesting studies, researches and developments related to the field. In the next sub-chapter, “haptics technology in mobile phone” will be explored and some examples will be introduced. Thereafter, haptics technology in mobile phone will be our primary focus from this point onward.

> *“But there is more to touch. It is a sense of communication. It is receptive, expressive, can communicate empathy. It can bring distant objects and people into proximity [69 ,p.1].”*

3.3 Haptic technology in mobile phone

> *“Your mobile phone is the first truly pervasive computer. It’s always with you, helping you keep in touch with others and manage everyday tasks. Technological advances mean that manufacturers can pack ever more features into the small, convenient form factor. Smart phones can already see, hear, and sense their environments [84, p.70].”*

Mobile phones, dramatically becoming omnipresent, as well as being part of everyday life and their occurrence makes them ideal for not only communication technologies where popularity is transforming them from simple voice-communication devices to advanced-communication devices that provide voice, text, and video messaging but also for entertainment and gaming industry. Recent commercial mobile phones are becoming more sophisticated and highly intractable to all three majors senses the human namely touch, vision, and hearing sense. Similar to the camera, which added interest and utility to the mobile experience, the touch system can improve interactivity and usability. Increasingly, computing functions such as e-mail, web access, and spreadsheets have been added to the repertory of mobile phones [85].

In 2006 Subramanya and Yi [85] explained that *“The next generation of mobile systems will operate on a core Internet Protocol network that supports all popular operating systems and software applications. Their high data rates and low latencies, together with their increasing capabilities, will help mobile phones facilitate the delivery of rich multimedia services such as video telephony; streaming news, sports, and movies; and multimedia messaging, Web browsing, and games. Statistics from the first quarter of 2005 show the use of mobile content and applications in the US grew across all segments, with mobile games attracting 6.23 million users, photo messages 12.24 million, ringtone downloads 23.09 million, and text messaging 65.68 million. Analysts expect this enormous growth to continue in the near future [85, p.85].”* Hence, user interfaces for mobile devices play an important part in supporting a pleasant user experience, for this reason the design of simply but effective interfaces for mobile content is considered to be a top priority [85].

Particularly at this point in time, we could agree that it is an undeniable fact that mobile phone is becoming an important piece of accessories in our daily lives. The improvements of their designs, and functionalities have rapidly evolved. Whereas the interfaces might be regarded as the primary concern when designing user interfaces as well as any kind of applications for the mobile phones to offer a pleasant experiences for customers. We could see that in doing so, developers ought to give consideration to various inputs and elements that could potentially help in improving their designs. Haptic feedback has come to light as a noteworthy feedback, which exploits one of human sense namely, touch. Haptic feedback in mobile phone has been utilized and improved over the years. There are many studies related to haptic feedback in mobile phone. Therefore, I am going to explore the related studies in this sub-chapter from the past to the present.

> *"Smart phones' emerging capabilities are fueling a rise in the use of mobile phones as input devices to such resources as situated displays, vending machines, and home appliances. Mobile phones' prevalence gives them great potential to be the default physical interface for ubiquitous computing applications [84, p.70]."*

3.3.1 Delve into the past

In 2002 Poupyrev et al. [86] examined the sense of touch as a channel for communicating with small portable devices. Their studies discovered that tactile actuator that was designed particularly to use in mobile interfaces to execute from simple clicks to complex vibrotactile patterns demonstrated 22% faster task completion when they enhanced portable tilting interfaces with tactile feedback [86].

Later on in 2003 Poupyrev and Maruyama [87] stated that they assumed the use of touch screens will definitely grow in the future because touch screens have become common in mobile devices. Touch screens are alluring because of its functionalities where users can touch, push, and drag information directly with their fingers. Touch screens provide better user acceptance, ease of use and faster response rate [87].

In 2005 Chang and O'Sullivan [88] studied the new type of mobile phones which were built to allow vibration and audio stimulation, or audiohaptics. They applied two techniques, which include the Haptic Inheritance and Synthesis and Matching methods. The two methods of haptic media generation permitted simple generation of vibration content, as well as enabled for compatibility with non-haptic mobile devices. Their results revealed that users were receptive to audio-haptic user interface feedback, on top of that the results also suggested that audio-haptics seems to improve the perception of audio quality [88].

In 2006 Brown et al. [89] found an interesting results that could aid designers to recognize the possibilities provided by standard phone vibration motors for communicating complex information [89]. Furthermore in the same year Brown and Kaaresoja [90] presented fascinating results to help designers to choose applicable Tactons (tactile icons) to use when designing mobile displays [90]. They believe that by using greater complex vibrotactile messages would allow the communication of more information through phone alerts [89]. Tactons are structured vibrotactile messages which can be utilized for non-visual information presentation when visual displays are restricted [90].

Later on in September 2008 Hardy and Rukzio [91] presented "Touch & Interact" assuming that an interaction technique, in which allowed users to touch a display at any position on the screen performing tasks, would improve usability of the screen while using a mobile phone. At that moment in time, problem of the limited screen size and resolution initiating difficulties when using map, multimedia and browsing applications. In their studies, they revealed the implementation of Touch & Interact, its usage for a tourist guide application and experimental comparison. They had found that the performance of Touch & Interact was corresponding to approaches based on a touch screen; it also showed the advantages of their system concerning user friendliness, intuitiveness and satisfaction [91].

In May 2009 Inoue and Okamoto [92] presented an improvement of transparent flexible sheet that applied in haptic devices. It provided visual and haptic sensations when a user pushed a virtual soft object. User could feel the softness of the object by pushing the sheet [92].

Later in October 2009 Yatani and Truong [93] presented and introduced SemFeel a tactile feedback system, which informed the user regarding the presence of an object where user touched on the screen and also offered additional semantic information concerning that item. SemFeel could generate different patterns of vibration, such as ones that flow from right to left or from top to bottom, to assist users interacting with a mobile device. Their studies had shown that users could differentiate ten different patterns, including linear patterns and a circular pattern, at approximately 90% accuracy, and that SemFeel supports accurate eyes-free interactions [93].

Previous scientific studies served as a light in the dark, shining their way to attain our better understanding in haptic feedback applied in mobile phone. They have demonstrated some great benefits of tactile feedback for touch screen in e.g. performance, usability and user experience. Additionally, they have mentioned the possibilities and opportunities to grow for haptic technology in mobile phone. Further on in the following sub-chapters, I will explore the varieties of usages and benefits in haptic technology in mobile phone and few examples will be shown.

3.3.2 Make typing feel better

> *"Mobile user interfaces are commonly based on techniques developed for desktop computers in the 1970s, often including buttons, sliders, windows and progress bars. These can be hard to use on the move, which then limits the way we use our devices and the applications on them [94, p.151]."*

Early in 2003 Nashel and Razzaque [95] presented a technique to apply the tactile hints of real buttons to virtual buttons presented on mobile devices with touch screens. When the finger of users was on the display, tactile feedback transmits a feeling of button location and stimulation. Additionally, they described two implementations of the technique using a PDA and a force sensitive tablet [95].

In 2007 Brewster et al. [10] examined the use of vibrotactile feedback for touch-screen keyboards on PDAs. Their results demonstrated that with tactile feedback users entered considerably more text, made fewer errors and corrected more of the errors they did make. Their results suggested that tactile feedback plays significant part in elevating interactions with touch screens [10].

In April 2008 Hoggan et al. [96] explained in their studies that by adding tactile feedback to the touchscreen, it considerably enhanced finger-based text entry, offering much better performance, experiencing virtually like having a real physical keyboard. Their second experiment revealed that higher specification tactile actuators could improve effectiveness even further. The outcome suggested that manufacturers should use tactile feedback in their touchscreen devices to retrieve the reduced feeling of touch when interacting on a touchscreen with a finger [96].

Shortly after in October 2008 Koskinen et al. [97] desired to progress understanding in the characteristics of a tactile click for virtual buttons to discover a tactile click which was the most enjoyable to use with a finger. They utilized two actuator solutions in a small mobile touch screen: piezo actuators or a standard vibration motor in their experiments. They discovered that tactile feedback was better to a non-tactile condition when using virtual buttons with the finger regardless of the technology supporting the tactile feedback. Additionally, they noticed that the users sensed the feedback done with piezo actuators somewhat more pleasing than the vibration motor based feedback, although not statistically notably. These outcomes suggested that it was feasible to modify the characteristics regarding the virtual button tactile clicks towards the most pleasant ones, furthermore this knowledge can assist designers to produce better touch screen virtual buttons and keyboards [97].

In 2011 Kaaresoja et al. [98] explained that touchscreens were widely used, particularly in mobile devices. Even though there are many preceding studies, which demonstrated the benefits of tactile feedback in touchscreen interaction, the impact of the apparent latency in interaction in fact had been overlooked. Their studies had shown that users considered the keypad with the shortest feedback latency more soothing to use. They concluded that latency made the user experience worse, even though performance did not noticeably decrease [98].

Additionally in the same year Kaaresoja et al. [99] found that users appeared to perceive buttons with longer delays as heavier. Users felt that they needed to use more force when pressing. The results suggested that to represent tactile weight in touchscreen interaction, we could do so by using different latencies [99].

In 2014 Tani and Yamada [100] explained that while users typed on touchscreen, many mistakes had happened because buttons were lacked of physical boundaries. The input accuracy of touch-panel devices was considered to be lower than that of devices with physical buttons. Thus, they proposed a more practical model for improving input accuracy, in which the relative relationships between a target object and neighbor object that might influence error making when touching the target are tested [100]. Shortly in 2015, they [101] proposed a model for improving input accuracy in which the tap model includes cognitive errors to avoid tapping neighboring objects to a target object. They considered that their model can describe important properties for designing various user interfaces depending on practical applications [101].

3.3.3 Make a world a better place

> *"Haptics is an important development for human-computer interaction since most haptic devices are unique I/O devices having 3-D manipulatory ability in addition to tactile and kinesthetic display. Combined with sound, haptics can create a viable alternative interface for blind and visually impaired people [102, p.83]."*

In 2007 Kuber et al. [103] explained in their studies that they believed haptic technologies have the potential to aid blind persons manage the difficulties when using the Web. Their research intends to culminate in a framework, encompassing a vocabulary of haptic sensations with associating suggestions for designers to address when developing inclusive web solutions [103].

In 2010 Jayant et al. [104] described that they had preliminary research with deaf blind Braille users who depend mainly on their tactile sense. They introduced V-Braille that was a revolutionary approach to represent Braille characters on a regular mobile phone using the touch-screen and vibration. Because of the V-Braille, they discovered that, with only minimal training, V-Braille could be used to read each characters and sentences [104].

In the same year Kulyukin and Kutiyanawala [105] presented ShopMobile II which was a mobile shopping system for virtually impaired individuals. This study was based on the fact that supermarkets are one of the most functionally frustrating surroundings for visually impaired individuals. ShopMobile II was then implemented on the Google Nexus One smartphone. They demonstrated how haptic and audio interfaces enhance simple vision techniques. In addition to that they presented an interactive haptic feedback loop to align the mobile phone camera with fixed surfaces in the pitch and yaw planes [105].

In 2011 Akhter et al. [106] studied *"Haptic Vision Substitution"* which was a reasonably new "*Human- Machine Interface"* created to assist the blind to 'see' through touch. They presented the implementation and design of a Smartphone-based vibrotactile system that utilized Catadioptric stereo imaging to enhance the spatial awareness of a visually impaired individual. Their studies also included research on the efficiency of the haptic transduction and techniques of enhancing the tactile sensation to deliver a smoother user experience [106].

In January 2015 Choudhary et al. [107] suggested an innovative approach to support the communication and interaction of deaf blind individuals by promoting their independence. They believed that with their approach they could help deaf blind individuals to have better connection with information and communication. Their strategy provided a smart glove that translated the Braille alphabet into text and vice versa, as well as communicated the message via SMS to a remote contact. It allowed user to express simple messages by capacitive touch sensors as input sensors positioned on the palmer side of the glove, then converted to text by the PC/mobile phone. The wearer could understand incoming messages by tactile feedback patterns of mini vibrational motors on the backside of the glove. Their successful implementation of real-time two-way translation between English and Braille, and interaction of the wearable device with a mobile phone/PC manifested new possibilities of exchanging information between deaf blind individuals, for instance remote interaction, along with parallel one-to many broadcast. The glove also made communicating with laypersons without knowing Braille feasible [107].

Shortly after in March 2015 Srivastava et al. [108] explored how multimodal interfaces could be utilized to educate Braille quicker and more successfully. Mudra was an interface to teach Braille which had been made intuitive by integrating speech recognition, tactile and audio feedback. A development of a prototype utilized a mobile phone application, Raspberry Pi based single cell refreshable Braille display and audio headset [108].

Later in May 2015 Nicolau et al. [109] proposed HoliBraille which was a system that enabled Braille input and output on existing mobile devices. They applied vibrotactile motors together with dampening materials to be able to operate directly on fingers of users. The prototype was able to be attached to existing capacitive touchscreen devices allowing multipoint and localized feedback. HoliBraille could be leveraged in several applications including educational tools for learning Braille, as a communication device for deaf blind people, and as a tactile feedback system for multitouch Braille input. After their studies, results had shown that HoliBraille was effective in providing localized feedback [109].

Soon after in June 2015 Nomiyama et al. [110] presented a two-tap based user interface system to decrease the impediment on motor-impaired company employees by using a touch-type gadget for instance a tablet or smart phone. Their system revealed its efficiency in the preliminary experiment for the motor-impaired company employees. Their system helped the workers to send texts to an application on a daily-use PC via a Web browser. Users could personalize the key layout to meet their requirements. Their system had shown its usefulness, thus they showed an interest in implementing it at their places of business [110].

Later in December 2015 Toshniwal et al. [111] proposed VibRein to improve the student interaction with multimedia learning content by utilizing different sensors that were available on a mobile gadget. VibRein was shown to be beneficial for students with intellectual disabilities who required consistent support. It offered an assistive system that monitored the user attention utilizing the device camera as well as a haptic feedback to gain their attention. Their research suggested that VibRein could provide better learning with less intervention [111].

3.3.4 Make lives easier

In 2007 Turunen et al. [112] presented a design of a rich multimodal interface for mobile route guidance. The application provided public transport information in Finland, including help for pedestrian guidance when the individuals changed their types of transportation. The preference of input and output modalities consist of speech synthesis, speech recognition, a fish eye GUI, haptics, contextual text input, physical browsing, physical gestures, non-speech audio, and global positioning information. Collectively, these modalities provided an interface that was available for a variety of users including persons with different levels of visual impairment [112].

In 2011 Jacob et al. [82] described four haptic feedback-based prototypes for pedestrian navigation. Haptics was utilized to show location, orientation, and distance information to users using pedestrian navigation applications [82].

In 2015 Feng et al. [113] presented two user studies which examine the effectiveness of utilizing pressure as an alternative input technique to touch when using mobile phones while e.g. walking and caring shopping bags. They put force-sensing resistors around the edges of a mobile phone in order to offer multiple pressure points to execute on-screen spreading, pinching, rotating and dragging single handedly. Their preliminary studies indicated promise with using multidigit pressure input to improve one-handed touchless interactions with portable devices in multitasking encumbered contexts [113].

In the same year O'Neil et al. [114] aimed to design and build a operational system to facilitate patients of their rehabilitation after enduring a stroke. A stroke is one of the most severe conditions that a person might experience and suffer from, while the rehabilitation is usually an extensive and difficult process. The sit-to-stand exercise is a significant step in rehabilitation for many with motion effects. They focused on create a system to assist sit-to-stand rehabilitation with the use of haptic feedback on stability. They introduced their first prototype using standard smartphone accelerometers linked wirelessly to Arduino based vibration feedback modules mounted on the legs of patients. The feedback on their prototype was assuring [114].

3.3.5 Help protecting yourself

In 2011 Bianchi et al. [115] described the design, implementation and assessment of a PIN entry technique based on audio or haptic hints that is proper to merge into current systems. Their studies had shown that the validity of this method on task times and error rates improved over present techniques. It unveiled the prospective of non-visual PINs as a mechanism for safe-guarding access to various systems such as guarding mobile phones [115].

In June 2015 Yang et al. [116] introduced TapLock as a smartphone password technique that utilized the finger tap activities on capacitive touch displays for elevating the resilience of password to help protecting users from people who might observe their password by simply standing over their shoulders. TapLock captures the size and the axis length of the finger touch area on the phone screen for generating a password, which cannot be conveniently observed by others. Their study had revealed that TapLock had multiple benefits over current smartphone password techniques, particularly its strong attack resilience, small authentication delay, and haptic input feedback that improves the usability [116].

Later in 2015 Findling and Mayrhofer [117] explained in their study that individuals normally verify themselves when accessing their mobile phone devices however devices do not do the same. It could happen that attackers replace the real device with an identical-looking malicious device to acquire the authentication secret. Based on the aforementioned situation, they had studied vibration as one device-to-user feedback channel that is unobtrusive and difficult to eavesdrop, incorporating with a user study to analyze vibration pattern recognition. They had found that users were able to recognize vibration patterns with median correctness of 97.5% (without taking training effects into account) which suggested that vibration could act as authentication feedback channel and should be examined further in the future study [117] .

3.3.6 Offer enjoyment while playing games

In 2007 ur-Rehman et al. [118] suggested a new technique to perform a live football game on mobile phones by utilizing vibration. The mobile phone was synchronized with the ball in the real-time football game. Users were able to experience vibrant motions of the ball, to understand attacking details and to recognize which team was leading the attack simply by holding the phone. By concentrating on the vibrotactile functionality of the mobile, it indicated that it offered an improved and more entertaining user interaction, make content more realistic, and operation more intuitive [118] .

In 2013 Esposito and Lenay [119] proposed "FeelTact" project concerning the design of the mobile game which offered a revolutionary strategy that did not use the screen as the main output device. Based on the fact that generally while playing games, players must stop to look at their screens thus players often had a problem of disconnection from their surroundings. The FeelTact project concentrated on optimizing rich tactile feedback, in contrast to simple vibrations. The FeelTact device is a new kind of tactile wristband that would drive the information a player receives. The first FeelTact game was an audiotactile mobile game based on an urban navigation system. Their outcome was reasonably appealing and revealed that it is possible to exploit a new tactile dimension that has been formerly underused [119].

In 2015 Zou et al. [120] introduced an android mobile game Eco Eco. It was designed to illustrate the concept and also to test the efficiency of the system for young users. This Farmville-like game intended to enlighten young children with environmental concepts as well as motivating them to commit to real-life green habits [120].

3.3.7 Connect with an interactive world

In 2011 Jin and Park [121] proposed an interactive Mobile Augmented Reality system utilizing a pad that is vibrotactile. The proposed system can offer vibrotactile feedback for realistic immersive experience. For interactive Mobile Augmented Reality, they concentrated on delivering expressions augmented movements and location information of objects utilizing vibration motors. By using basic memory test application, they confirmed that the proposed system is useful for offering intuitive knowledge for information of augmented movements and location of objects [121].

In 2014 Wei et al. [122] evaluated two non-visual interaction modalities, haptic display and audio display, and their combination to describe tourism information to users with a mobile phone. The results showed a primary impact of interaction modality, with identification rate highest for information represented in the combined Haptic-Audio display at 86.7% [122].

3.3.8 See the world through our lens

In 2008 Brewster and Johnston [123] noticed that when users used mobile phone camera to take a photo, they frequently overlooked the icons exhibited around the sides that presented important information regarding the status of the camera. They considered that pictures could be missed or poorly exposed. Consequently, they created a sonified luminance histogram to provide exposure information, a sound cue to show memory space remaining and a tactile cue for battery charge status. A user study revealed that participants had the ability to utilize the sonified histogram to determine exposure effectively and could recognize the status associated with the battery and memory card correctly. They proposed that alternative kinds of output could free-up the screen for framing the image [123].

In January 2010 Jayant [124] investigated common camera interaction techniques, mobile device and camera accessibility for blind users, and computer vision techniques for recognition considering mobile phone restrictions. Based on the fact that mobile devices and their sensors, along with audio or tactile output, exhibited astounding potential for improved daily accessibility to the world for blind people on the go. Especially, the camera has the potential to broaden environmental knowledge utilizing context and computer vision. These studies along with formative studies and focus groups with users would enlighten the design, implementation, and evaluation of future lab and field studies for semi-autonomous focalization with the camera for blind users [124] .

In 2014 Low et al. [125] proposed a method to detect pressure asserted on a mobile phone by utilizing the back camera and flash on the mobile phone. When putting a mobile phone on the palm, there is clearly a space between the palm and camera. In this situation, it allows the light from the flashlight to be reflected towards the camera. On the contrary, when applying a pressure on the phone, it is reducing that space as well as reducing the brightness captured by the camera. This occurrence is employed to determine two gestures: pressure applied on the screen and pressure applied when user squeezes the phone. Additionally, they performed an experiment to identify the noticeable improvement in brightness degree with respect to the quantity of force asserted in the phone when placing it in two positions: parallel to the palm and perpendicular to the palm. The outcome revealed that whenever the force increases, the brightness level decreases. Using the phones ability to detect fluctuations in brightness, various pressure interaction applications such as for gaming purposes might be developed [125].

3.4 Summary

On top of all the studies I have explored in this chapter, there are numerous studies related to haptic technology in general domains for example tactile electronic interfaces/displays[1-14], multimodal interactions[15-21], tele-operators and simulators[22-30], gaming industries[31-35] [118], [120], mobile devices[36-44], virtual reality[45-53], medicine[54-58], robotics[59-67], automotive industries[68-71], and consumer electronics[72-81]. However, in this thesis we focus merely on haptic technology in mobile phones. Mobile phones have now become an essential gadget in our daily lives. They have evolved dramatically since first introduced. There has been countless number of studies related to mobile phone with respect to their potential, popularity, usability, and functionalities[82-96] [84], [85].

1-96 available at Appendix 4

4. A STUDY OF MOBILE PHONE CAMERA USAGE HABITS AND CHALLENGES

This chapter presents the methodology used in the observational part of the thesis. The thesis consists of one user study performed at the beginning of the thesis. The motivation, research goals, participants and the practical work behind these user studies are described below.

4.1 Research objectives

The user study was done at the beginning of the thesis work. The main objective was to analyse the user needs and expectations regarding to the mobile phone camera haptic feedback and applications in various type of difficult situations and challenges users have encountered in addition to provide input for the further studies as well as to provide concrete input to the development of the prototype. The aim was to get general results which can be applied to haptic interaction on the mobile phone camera in order to: improve the existing application and help easing users in their photo taking activities with their mobile phone camera.

The study of phone camera usage habits and challenges addresses the following research questions:

1. What kind of difficult situations and challenges users have encountered while taking photos with their mobile phone camera?
2. What kinds of expectations and needs users have regarding the user experience with mobile phone camera haptic feedback and application?
3. How could haptic feedback assist the way of taking photo easier?

4.2 Participants

I recruited eight participants from diverse user groups. The panel ranged from users who dislike taking photos with their mobile phone camera to those who like to perform such action. The divergence between participants can lead to interesting discussions and provide helpful insights. Participants might come across new point of view and help bringing up the new ideas.

The participants selected for the interview were all considerably technologically oriented and had an interest for the discussed topics. I believed the technical background of participants would initiate more ideas and make the discussion not only easier but also more innovative. In the first interview, participants described with the following characteristic:

- Users who are generally interested in new technology.
- Users who love taking photos with their mobile phone camera or/and DSLR camera or/and digital camera.
- Users who like challenges.
- Users who love traveling and travel abroad quite often.
- Users who take interest in sports (i.e.: mountain climbing and cycling).

4.3 Interview participants

Eight users took part in the interview. All of the participants had a university background. All of them were from Tampere university of Technology (3 female, 5 male). Their age ranged from 21 to 30 years old. All participants were foreigners in Finland (2 Indian, 1 Romanian, 1 Czech, 1 French, 1 Armenian and 2 Chinese) Two participants were researchers (one was from Machine Dynamic, another one was from Signal Processing). Three participants have completed their master's degree, and one of them was working as a software engineer. (M. Sc. Materials Science, M. Sc. Machine Automation, M. Sc. Information Technology). Other three participants were doing their Master's degree (all of them were from Information Technology, 2 were from Software systems and 1 was from Human-Centred Technology). All of the participants had experience with mobile phones, and different kinds of cameras. Furthermore, all of the participants had an interest in the topic as I looked for users with experiences in taking photo with their mobile phone camera and/or their digital camera and/or DSLR camera as well as familiar with touch interactive devices.

4.4 Interview session structure

The structures sessions followed a simple procedure to ensure all of the interviews followed the same structure. The structured approach provides the free area for a further discussion to open up for new ideas, opinions and experiences. This structures session also allowed us to explore the needs and expectations of users. Interview-like approach allowed us to ask clarifying questions and acquire detailed information about new topics that appeared during the discussions. The sessions followed the structure listed below.

1. Introduction of the interview goals and roles during the interview.
2. Permission to record the interview (Appendix 1).
3. Background questionnaire (Appendix 2).

4. Interview Participants (Appendix 3).
5. Further discussion according to interview questions.

The introduction was done at first to provide the background information to the participants regarding the area of discussion and the thesis goals. After that, participants decided if they wanted to grant the permission to record the interviews or not. If they granted the permission, participants signed the informed consent to participate in a research session after that, participants filled the background questionnaire at the start of the session. The interview began after warning participants about the recording. The sessions were recorded by the voice recorder application within my mobile phone. Participants were given a homemade dinner in return for their time and participation.

4.5 Research data analysis

There are many steps in research data analysis. In order to clarify the process I would like to explain each step in more details below.

- An audio record is needed

  While doing an interview, I was given a permission to record each session therefore I listened to audio record of each person times and times again to get the most accurate data I could.

- Make a note from the audio record

  After listening to each record, I made notes to make ensure I got all important information from each participant.

- Excel sheet is coming in handy

  Later on, each note were put and sorted in categories to see relationship among information from each participant. Put them in tables.

- Quotes are usually needed

  Once I start to see the whole picture and relationship among data. Sometimes quotes from participants are needed; therefore I listened to each record once again to make sure I get their word correctly word by word.

- Graphs and flowcharts help wonderfully

  Graphs and flowcharts are created to help readers to understand data in easier way and also to see summary of each sub-chapter in picture.

5. RESULTS OF THE STUDY OF PHONE CAMERA USAGE HABITS AND CHALLENGES

This chapter presents the results of the interviews concerning mobile phone camera usage, which is divided in four sub-chapters. Firstly presented, will be the usage habits of participants that were extracted from the questionnaire in conjunction with the first part of the interview. Secondly, the challenges and difficulties in taking photos with the current mobile phone camera of participants that were extracted from the second part of the interview including the discussions with the participants. Thirdly presented, will be the expectations for haptics mobile phone camera that were extracted from the final part of the interview including the discussions with the participants. Participants proposed many interesting new ideas that allowed further discussions. All ideas that emerged during those discussions are presented in sub-chapter three. At the end of the chapter, a summary of ideas for haptics in mobile phone camera use will be presented as a final sub-chapter.

5.1 Usage habits of participants

Participants were requested to participate in two activities. First activity was to fill their backgrounds in the questionnaire *(Appendix 2)*. Second part is to participate in the discussion related to their past experiences during the interview *(Appendix 3)*. The results were extracted and conclusions are listed below according to the frequency of using mobile phone camera from **Never** to **Daily** respectively as showed in ***Table 1***.

Table 1. *List of participants.*

ID	Nationality	Age Range	Gender	Profession or field of study	Frequency
P1	Romanian	21-30	Male	Researcher in Signal Processing Ph.D. student	**Never**
P2	Czech	21-30	Male	Researcher in Machine Dynamic	**Occasionally**
P3	Indian	21-30	Male	M. Sc. Materials Science	**Monthly**
P4	Indian	21-30	Male	Software Engineer M. Sc. Information Technology	**Weekly**
P5	Armenian	21-30	Female	Information Technology, Software system	**Weekly**
P6	Chinese	21-30	Female	Information Technology, Human-Centered Tech	**Weekly**
P7	French	21-30	Male	Information Technology, Software system	**Weekly**
P8	Chinese	21-30	Female	M.Sc. Machine Automation	**Daily**

The following sub-sections present in more depth related to the usage habits of participants. These categories are named respectively the *occasional usage* and the *frequent usage*.

5.1.1 Occasional usage

There were 3 participants out of 8 participants, participant **P1, P2,** and **P3** (*Table 1*) who used their mobile phone camera to take photo less than weekly basis.

Participant **P1** *(Table 1)* mentioned he had ***never*** used his mobile phone camera to take photo. He considered his phone to be used as a communication tool to perform and receive the calls and messages. He was having Nokia 2730 classic at the time of interview. His previous mobile phone was as simple as the current one. He was satisfied with his mobile phone as simple as it was. However, he mentioned later that

> *"I do not use the mobile phone camera much, the photos I take are only functional, to copy some written information."*

Although he did not own any smartphone for the moment, he had experience using them. Therefore, he was familiar with the haptic feedback provided by smartphones. The reasons he never took photos with his mobile phone were because: first, he owned a DSLR camera (Canon 1000D) and, second, he did not trust the quality of the mobile phone camera. He was an amateur photographer. He loved taking photo on a regular basis. He preferred to bring his DSLR camera with him to take photo during his favorite hobbies e.g. football, cycling, fishing, trekking, mountain climbing and obviously photography.

> *"I usually like to go hiking so I take a lot of pictures there. Also when cycling."* he mentioned.

Participant **P2** *(Table 1)* mentioned he took photos with his mobile phone camera ***occasionally***. He was having Samsung Galaxy SII at the time of interview; his previous mobile phone was Nokia N70. He was new to his smartphone. Considering that he was new to his smartphone, he took time to get familiar with the haptic feedback. He mentioned about the difficulties he had with haptic feedback as well as the satisfaction he had towards haptic feedback.

> *"To answer the phone call was difficult when the phone was new. I was unable to answer because I was pressing almost through the phone. It did not help. And then later I realized that I had to slide"*

> *"I like it exactly. I like the haptic feedback for example that when I touch something it vibrates slightly"*

Although he did not take photo with his mobile phone camera very often he mentioned that,

> *"It is quite easy"*

> *"I take photo of people, my friends usually or when I see a nice landscape or something funny"*

Participant **P3** *(Table 1)* mentioned he took photos with his mobile phone camera ***monthly***. He was also an amateur photographer. He owned Nikon D3000. He was having Nokia E7 at the time of interview, his previous mobile phone were Samsung Monte and Nokia N70. He also owned a tablet computer. Therefore he had experience with haptic feedback both from tablet and smartphone. He liked taking photos by his phone because its handiness therefore he did not have to carry his DSLR camera with him all the time. He preferred taking landscape photos.

> "*Landscape is something that you take when it is pleased your eyes.*"

Therefore he waited for the right moment and the right time to capture each photo. He mentioned that he liked the quality of the photos from his current mobile phone. Most of his photos were taken by using the touchscreen rather than the button because mobile phone would have been shaken when pressing. He is very familiar with haptic feedback he gave an example of surfing the internet with the mobile phone or tablet.

5.1.2 Frequent usage

There were 5 participants out of 8 participants, participant **P4, P5, P6, P7** and **P8** *(Table 1)* who used their mobile phone camera to take photo in weekly basis and more. Four participants **P4, P5, P6** and **P7** mentioned they took photos with their mobile phone camera weekly.

Participant **P4** *(Table 1)* mentioned he took photos with his mobile phone ***weekly.*** He was having Nokia 5130 music express and Nokia C7 at the time of interview. His previous phones were Nokia N97 and Nokia 900. He owned also a digital camera. He mentioned that he took photos when something seems interesting.

> *"I like taking photos with my mobile phone because it is easy, it is in my pocket and I do not have to carry other devices to take photo"*

He normally took either portrait photo or landscape. He was familiar with the haptic feedback because he had been using his smartphone and also he owned an ExoPC Slate.

Participant **P5** *(Table 1)* mentioned she took photos with her mobile phone ***weekly.*** She was having Nokia C7 at the time of interview. Her previous phone was a very simple

Nokia phone. She owned also a digital camera (Olympus EPL1). She mentioned that she liked to take landscape photos, or when she had to take something quick with her mobile phone camera. She mentioned she sometimes took portrait also.

> *"Well yes I do, but not all the time because it is worth taking something quick, short, but not high quality"*

She was very familiar with the haptic feedback because she had been using her smartphone and also she owned an ExoPC Slate and Kindle touch.

Participant **P6** *(Table 1)* mentioned she took photos with her mobile phone ***weekly.*** She was having HTC wildfire at the time of interview. She owned also a digital camera from Canon. She mentioned that she liked to take landscape photos, portrait, copying something for instance copying slide in the lecture, interesting to remember, and also she was interested in taking photos with "Lomo camera". To her not only that the mobile phone is portable, she considered a mobile phone camera as an additional function so the quality is acceptable as long as the photos can be seen clearly.

> *"Yes I like to take photos with my phone because it is portable, small, easily fit in your pocket."*

She was very familiar with the haptic feedback because she had been using her smartphone e.g. surfing the internet, and also she was considering buying an iPad in the future.

Participant **P7** *(Table 1)* mentioned he took photos with his mobile phone ***weekly.*** He was having Nokia C7 and E70 at the time of interview. He did not own any digital camera. He mentioned that he liked to take photos of scenery, object in a scene, photos of food and special moment. He mentioned also that travelling, hiking and cooking were his favorite hobbies that related to taking photos.

> *"Yes I like to take photos with my phone because it is quite fast so if something happens you just have to take your phone, press one or two times then photo is taken."*

He was very familiar with the haptic feedback because he had been using his smartphone e.g. playing games, and also he had an experience playing game with his game controller which provided haptic feedback.

Participant **P8** *(Table 1)* mentioned she took photos with her mobile phone camera ***daily.*** She was having Nokia 5530 at the time of interview. She own Nikon D3000. She mentioned that she liked to take landscape and portrait photos. She mentioned also that she liked to take photos of fun events and publish it on a social network e.g. Facebook.

> *"Yes I like to take photos with my phone because it is convenience."*

She was familiar with the haptic feedback because she had been using her mobile phone and also had an experience with a tablet.

5.1.3 Summary of usage habits of participants

The Usage habits of participants were studied, analyzed and extracted from the questionnaire and the first part of the interview with participants. Two distinctive groups of participants were defined in this study:

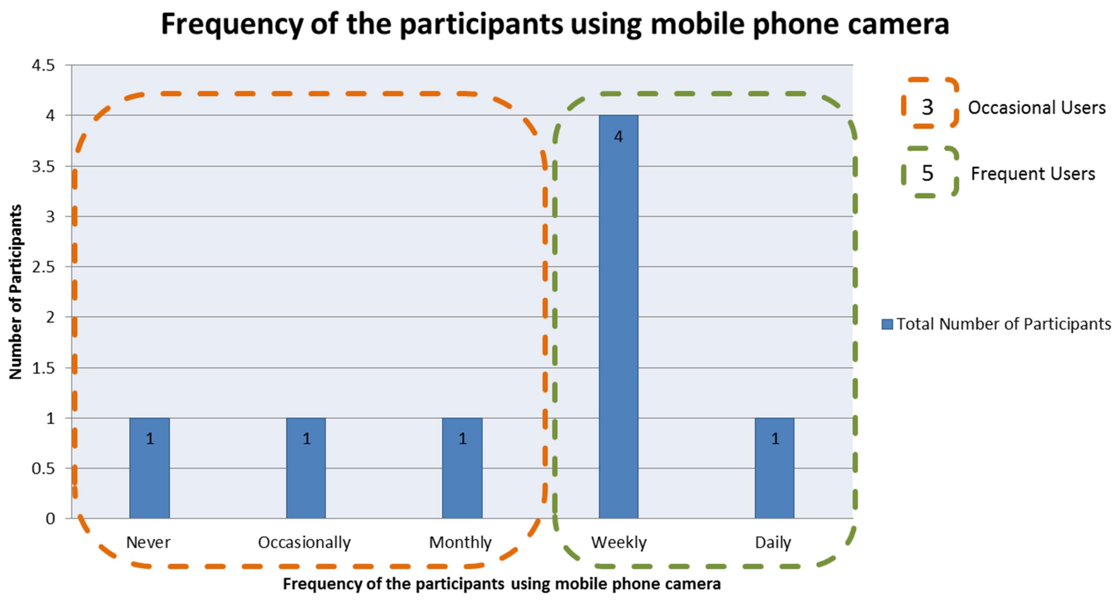

Figure 9. *Frequency of the participants using mobile phone camera*

The first group contains the occasional users, those who decided to use their mobile phone camera only when really necessary. The majority of this group owned a DSLR camera and considered photography as a hobby. They had high expectation for the results. Therefore when comparing the quality of the photo from their DSLR camera with their mobile phone pictures, they preferred the first ones, since the quality is much better, and, for this reason, the first group of participants rarely use their mobile phone camera. Nevertheless, the users agree that the advantages of mobile phone camera reside in the portability and accessibility.

The second group contains the frequent users, those who used their mobile phone from daily to weekly basis. They cherished the portability and accessibility of the mobile phone camera. When comparing the habits of these two groups of participants, this group valued collecting memories over the quality of the photo. They had accepted that the quality of the photos was not as high as their expectations but they were qualified to use for sharing with friends and family and they were good enough to keep for their memories.

5.2 Challenges and difficulties in taking photos with current mobile phone camera

The challenges and difficulties in taking photos that participants had encountered in their past experiences were extracted from the second part of the interview including the discussions with the participants *(Appendix 3)*. The results are categorized in ***Table 2*** and described with more details in sub-sections.

Table 2. *Challenges and difficulties from participants own experiences.*

Sub-Section	Challenges and Difficulties	Encountered by Participants
5.2.1	Low quality of photos	**P1 P2 P6 P8**
5.2.2	Limitation of zoom and focus abilities of the lens	**P2 P3 P4 P6 P8**
5.2.3*	Difficulties in using *physical buttons* and *virtual buttons*	**P2 P3 P4 P5 P6 P8**
5.2.4	The unavailability of the auto-timing photography function	**P4**
5.2.5	The lack of standard in mobile phone camera user interface	**P4**
5.2.6	The application and lens focus takes long time to launch	**P7**
5.2.7*	Difficulties in taking photo in the darkness and artificial light	**P2 P5 P7**
5.2.8*	Difficulties in accessing the setting functions	**P1 P3 P8**
5.2.9*	Difficulties in taking photos while moving or while object was moving	**P1 P2 P3 P4 P5 P6 P7 P8**

Sub-sections that were marked with * have been deemed important enough by the participants to be the main point of focus for further haptic feedback development, a clarification will be provided in further sub-section 5.2.10 and sub-chapter 5.4

5.2.1 Low quality of photos

Participant **P1** mentioned he did not trust the quality of the mobile phone camera while participant **P6** and **P8** did share the same opinion on the low quality of the photos taken by mobile phone camera. However both participant **P6** and **P8** mentioned that it is acceptable. Participant **P6** mentioned that

> *"I think the camera on cell phone is just one additional function for me so I don't really care if it is ok to take picture and it can show clearly and if it can show it clearly on my pc."*

Participant **P2** did have the same opinion he said

> *"Mobile phone has that restriction there that you don't have the zoom. You cannot take photo with that good quality as DSRL camera but other than that it is good"*

5.2.2 Limitation of zoom and focus abilities of the lens

Participant **P2, P3, P4, P6** and **P8** mentioned there were many situations when taking photos by mobile phone camera was obstructed because of limited abilities of the lens for example the abilities to zoom and to focus.

5.2.3 Difficulties in using physical buttons and virtual buttons

There are two physical and virtual buttons that were mentioned which are “Zoom” button and “Focus” buttons that some participants had difficulties with.

Participant **P2 P3 P5 P6** and **P8** mentioned they had problems with using the physical buttons in the situation that touch screen is inaccessible.

Participant **P2** and **P6** mentioned they had difficulties using the Zoom button that is located at a side button of their mobile phone.

Participant **P3, P5** and **P8** mentioned that it is very difficult to focus photo both with physical focus button and virtual one on touch screen. Because with physical button, the phone was easily shaking however while using virtual focus button on touch screen, it was difficult to lock the focus in many situations for instance while participants were unstable.

Participant **P5** mentioned that she always had the difficulties taking photos during winter wearing gloves. She mentioned it was impossible to use the touch screen during winter so it was impossible to take photos with the virtual focus button on touch screen. However she mentioned that to use the physical focus button to take photo, it leaded to the result of unclear photo because of its shaking.

Participant **P4** and **P6** mentioned that their current mobile phones provided only the virtual focus on touchscreen to focus and capture the photo.

Participant **P4** mentioned it would be better if the phone could have provided also the button to take photo so that in some situation that touch screen is inaccessible he will be able to take photo.

Participant **P6** mentioned that it was very difficult to take photo with the only virtual focus button because the button was locked and positioned in one place. She could not touch anywhere else to take photo so she had to be very precise. She mentioned that to take her own photo was considered challenging when turning her mobile phone another way without seeing the precise position of the virtual focus button.

5.2.4 The unavailability of the auto-timing photography function

Participant **P4** mentioned he had the difficulties having a group photo. It was very difficult for him to ask other people to take photo because not everyone will be familiar with the same type of phone he was having. Also he did not want to bother other people to take his group photo.

5.2.5 The lack of standard in mobile phone camera user interface

Participant **P4** mentioned that it would be nice if all the mobile phone cameras would have standard applications and user interface. So that when he has to lend his phone to someone to take his photo everyone will be familiar with the application and interface so that it will be easy for everyone to use and to notice the function of mobile phone camera.

5.2.6 The application and lens focus takes long time to launch

Participant **P7** mentioned that his mobile phone camera application took time to launch. Consequently, he missed so many photos that he intended to capture because by the moment he wanted to take photo, the moment had been gone due to the time of focusing and other technical problems. He mentioned also the problem of focusing that once the photo was taken, he could not realize because there was no warning.

5.2.7 Difficulties in taking photos in the darkness and artificial light

Participant **P2** **P5** and **P7** mentioned that they had the difficulties in taking photo in the darkness. They mentioned that in the dark, they were unable to focus anything to take photo.

Participant **P5** referred to her past experience with natural light, that when the light was not enough, the quality of the photo was very poor.

Participant **P2** also pointed out the difficulties while taking photos in the artificial light for example when he wanted to take photo of his friends while hanging out together at the café during the night. It was almost impossible to get the proper photo from such situations.

5.2.8 Difficulties in accessing the setting functions

Participant **P1** thought that, not only the number of settings available on mobile phone camera was too few but the access to the settings in mobile phone camera was quite complicated and difficult.

> *"No, I don't like the quality of the photos taken and also it is quite hard to set settings on the phone"*

> *"Usually for my phones (not the best ones) the camera has a really bad performance, the noise is really high and the compression and de-noising algorithms are really not helping. They damage the quality further"*

> *"Add more control over the settings maybe without asking precise info from the user. Sliders and buttons should do the trick."*

Accordingly, he preferred to carry his DSLR camera to use when he wanted, despite its size. On the other hand, he admitted that he missed many photos when he did not carry his DSLR with him. He agreed that mobile phone camera was quite convenient in that sense. He said he would consider using the mobile phone camera if: the quality was better, the settings were easier to access, and more manageable in difficult situations.

Participant **P3** did have the same opinion towards the difficulties in setting and the limited options that were provided in the phone camera. He gave one example from his experience when he missed the important photo because he could not assemble his camera that fast enough and the mobile phone camera was unable to capture it.

Participant **P8** did share the same opinion towards the difficulties on accessing the settings of mobile phone camera. She mentioned that they were too many level of hierarchies to each settings. It was not easily accessible.

5.2.9 Difficulties in taking photos while moving or while object was moving

All participants mentioned that they had difficulties taking photo while they were moving or while the target was moving. They mentioned that it was very difficult to focus and capture any photos in both scenarios. Due to the light weight of mobile phone itself, it was already difficult to handle its shaking. With moving target either with normal speed or fast speed, photos were usually blurred. The results were deemed unacceptable.

5.2.10 Summary of challenges and difficulties in taking photos with current mobile phone camera

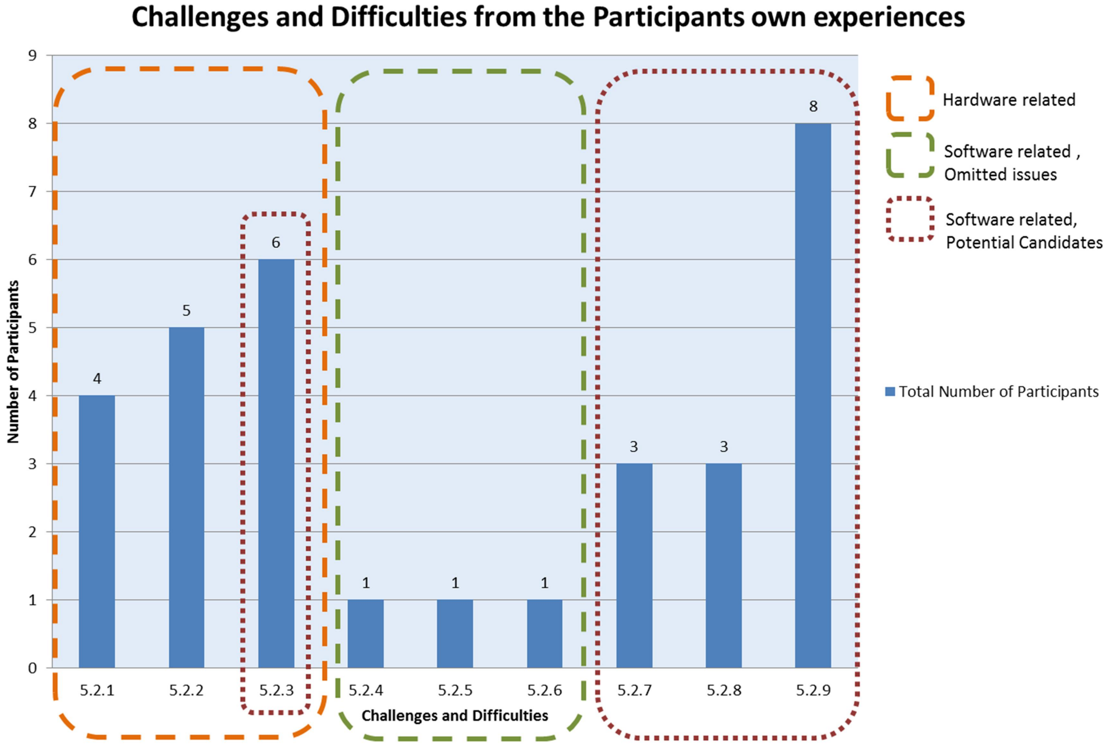

Figure 10. *Challenges and difficulties from the participants own experiences*

Challenges and difficulties in taking photo with current mobile phone camera were studied, analyzed and extracted from the second part of the interview with participants. They could be categorized following two discrete criterions:

The first criterion is the hardware related issue. There are three challenges and difficulties that are related:

- Low quality of photos (mentioned by four participants)
- Limited zoom and focus abilities of the lens (mentioned by five participants)
- Difficulties in using physical buttons (mentioned by six participants)

Despite the fact that many participants had mentioned these issues, these are hardware-dependent problems, which require the suppliers and the mobile phone manufacturers to upgrade their products. Thus, in the final analysis, these mentioned issues are beyond exploiting the haptic feedback. Ultimately, all hardware related issues will be omitted in further discussions for the haptic feedback development.

The second criterion is the software related issues. There are seven challenges and difficulties related to this topic, which can be subdivided in two categories.

The first sub-category contains:

- Difficulties in using virtual buttons (mentioned by six participants)
- Difficulties in taking photo in the darkness and artificial light (mentioned by three participants)
- Difficulties in accessing the setting functions (mentioned by three participants)
- Difficulties in taking photos while moving or while object was moving (mentioned by all participants)

Many participants mentioned these issues and they tend to have a potential to be candidates in further discussions about haptic feedback development as well.

On the other hand, the second sub-category contains:

- The unavailability of the auto-timing photography function (mentioned by one participant)
- The lack of standard in mobile phone camera user interface (mentioned by one participant)
- The application and lens focus takes long time to launch (mentioned by one participant)

These issues were mentioned by only few participants, as can be seen from ***Table 2*** where only one participant mentioned each issue. All these three will be omitted in further discussions for the haptic feedback development because firstly, many participants did not mention them, and secondly, each issue is not directly related to the haptic feedback. Thus, applying the haptic feedback will not likely resolve these issues.

Finally, only four challenges and difficulties which are: *difficulties in taking photo in the darkness and artificial light (5.2.7), difficulties in using virtual buttons (5.2.3), difficulties in accessing the setting functions (5.2.8), and difficulties in taking photos while moving or while object was moving (5.2.9)* will be taken in to consideration for the further discussions.

5.3 Expectations for haptics mobile phone camera

Expectations for haptics mobile phone camera were extracted from the final part of the interview and the discussion with the participants *(Appendix 3)*. Many suggestions and expectations were retrieved from the participants to improve the quality of mobile phone camera. Nonetheless, in this thesis we will focus only on the expectations related to the haptic feedback. The expectations for haptics mobile phone camera that were acquired from participants are categorized and described below. ***Table 3*** presents an overview of the sub-sections and the relevance of participants' own experiences with their expectations.

Table 3. *Haptic feedback to be applied on mobile phone camera in different scenarios.*

Sub-Section	Haptic feedback to be used	Scenarios	Relation to the challenges and difficulties from Table 2
5.3.1	Vibration	When pressing the button to focus*	5.2.3
		When a photo is taken*	5.2.3
		When users or targets are unstable*	5.2.9
5.3.2	Vibrotactile	When it is dark When the natural light is very poor When the artificial light is very poor	5.2.7, 5.2.8
		When pressing the button to focus*	5.2.3, 5.2.8

Scenarios that were marked with * have been deemed important enough by the participants to be the main point of focus for haptic feedback development. A clarification will be provided in further sub-section 5.3.3 and sub-chapter 5.4

5.3.1 A small vibration in different situations

Participants suggested that mobile phone camera should provide a small vibration to enhance its efficiency. A small vibration is considered to be beneficial in many different situations according to the participants' own experiences. Different situations and the expectations of participants are categorized and described below in ***Table 4***.

Table 4. *Vibration to be used in different situations in order to meet expectations from participants.*

Situations in which vibration may be helpful	Expectations from participants
When pressing the button to focus *Haptic Feedback 1 (Figure 6)*	Participants expected to have a small vibration when the photo is focused to give the same feeling when using a DSLR camera that when the focus button is half pressed, it gives vibration so users know that focus is now locked.
When users or targets are unstable *Haptic Feedback 2 (Figure 6)*	Participants expected to have some feedback or some indication to inform that users were unstable.
When photo is taken *Haptic Feedback 3 (Figure 6)*	Participants expected to have some feedback after photo is taken. Some participants mentioned audio and visual feedback; however participants considered a small vibration to be more practical and helpful than other different kinds.

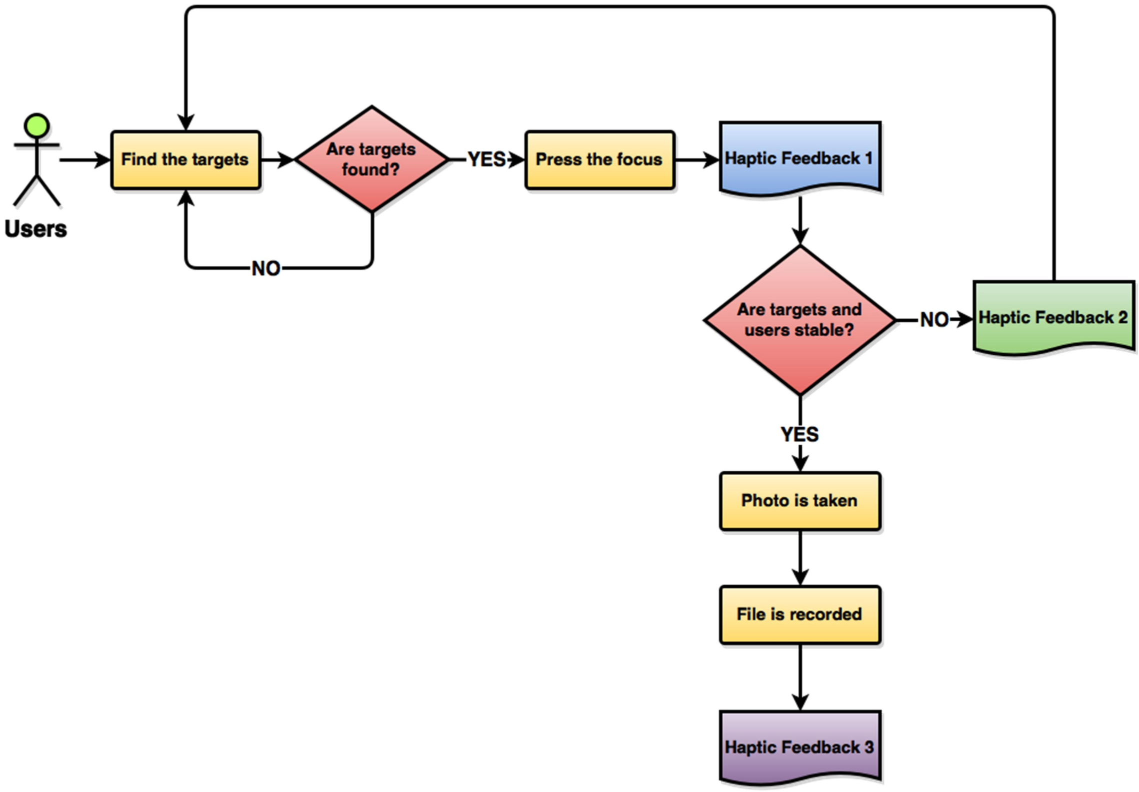

Figure 11. *Flowchart diagram showing the situations in which vibration may be helpful*

Figure 11 explains how vibration will be helpful in selected situation to ease users while using haptic mobile phone camera. Haptic Feedback 1, Haptic Feedback 2, and Haptic Feedback 3 represent mobile phone vibration feedback that users would feel whenever each action happens.

5.3.2 Vibrotactile feedback to help users with using the application and interface

Participants suggested that mobile phone camera should provide an easy interface to use in every situations, especially in a very difficult situations for photography, mobile phone camera should be able to assist users in taking photo if needed. Different situations and the expectations of participants are categorized and described below in ***Table 5***.

Table 5. *Vibrotactile to be used in different situations in order to meet expectations from participants.*

Situations in which vibrotactile feedback will be helpful	Expectations from participants
When it is dark When the natural light is very poor When the artificial light is very poor *Vibrotactile 1 (Figure 7)*	Participants expected assistances features from the mobile phone camera in such situations. Even though flash is one of the solutions, the quality of the photo was still quite poor. Participants suggested that if in such situation, a mobile phone camera is able to detect that it is difficult for photography, it then pop-up an assistant function with the easy access for settings to help taking photo in difficult situations.
When pressing the button to focus *Vibrotactile 2 (Figure 7)*	Participants expected to have some feedback when pressing the virtual button to focus on the screen. Participants suggested that the mobile phone camera should allow users to focus and take photo from touching any position on touch screen. Therefore to help participants in taking photo, vibrotactile is considered helpful especially in the situation that users can't see the screen while touching.

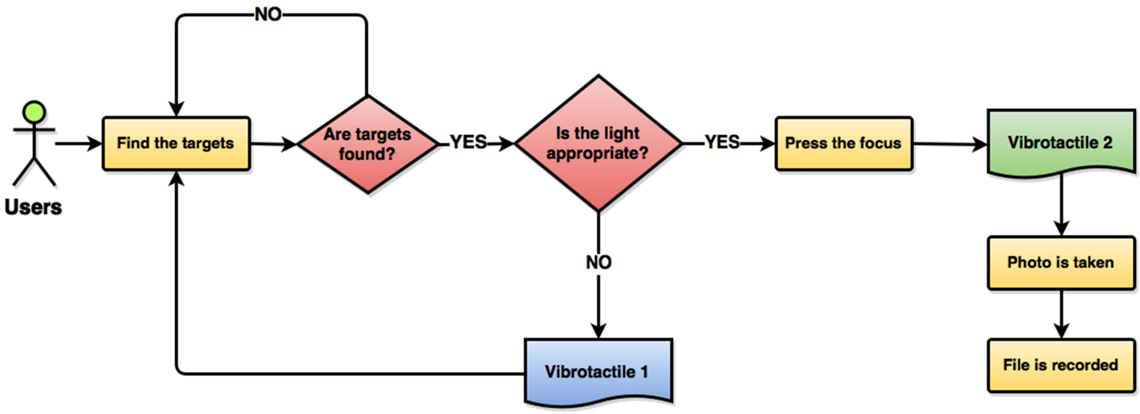

Figure 12. *Flowchart diagram showing the situations in which vibrotactile may be helpful*

Figure 12 explains how vibrotactile will be helpful in selected situation to ease users while using haptic mobile phone camera. Haptic Feedback 1, Haptic Feedback 2, and Haptic Feedback 3 represent mobile phone vibrotactile feedback that users would feel whenever each action happens.

5.4 Summary of ideas for haptics in mobile phone camera use

In first sub chapter, we have learnt that the relationship between users and the used of the mobile phone camera were depended on for example the quality of the photos by a mobile phone camera, the functionally and accessibility of a mobile phone camera and the ability of the mobile phone camera itself. From this sub chapter we have learnt that if mobile phone cameras manufacturers improve their quality, the first group might use their phone even more often. The second group would feel happier and continue to use their mobile phone camera regardless.

In the second sub chapter, we have learnt that users have encountered many challenges and difficulties in taking photos with their mobile phone cameras, which we can classify them to two categories; first the hardware part and second the software part. We are not capable to do anything with hardware related issues for instance to improve better lens or the quality of a flash, on the other hand, when it is the software related issues, some of them we can use haptics to help lives of users to get even easier and better in taking photos.

In the third sub chapter, we have learnt that some expectations from users could be used for future implementation for vibration and vibrotactile feedback. However, due to its nature feedback such as vibration is not good for many situations as mentioned. Vibrotactile might actually serve users better in many situations.

In the conclusion, we have narrowed down to our choices for a possibility of future implementation. The best choices were selected to focus on, which will benefit both developers and users at their best interest.

Figure 13 shows a flowchart diagram how to apply vibrotactile feedback to the camera application for future development.

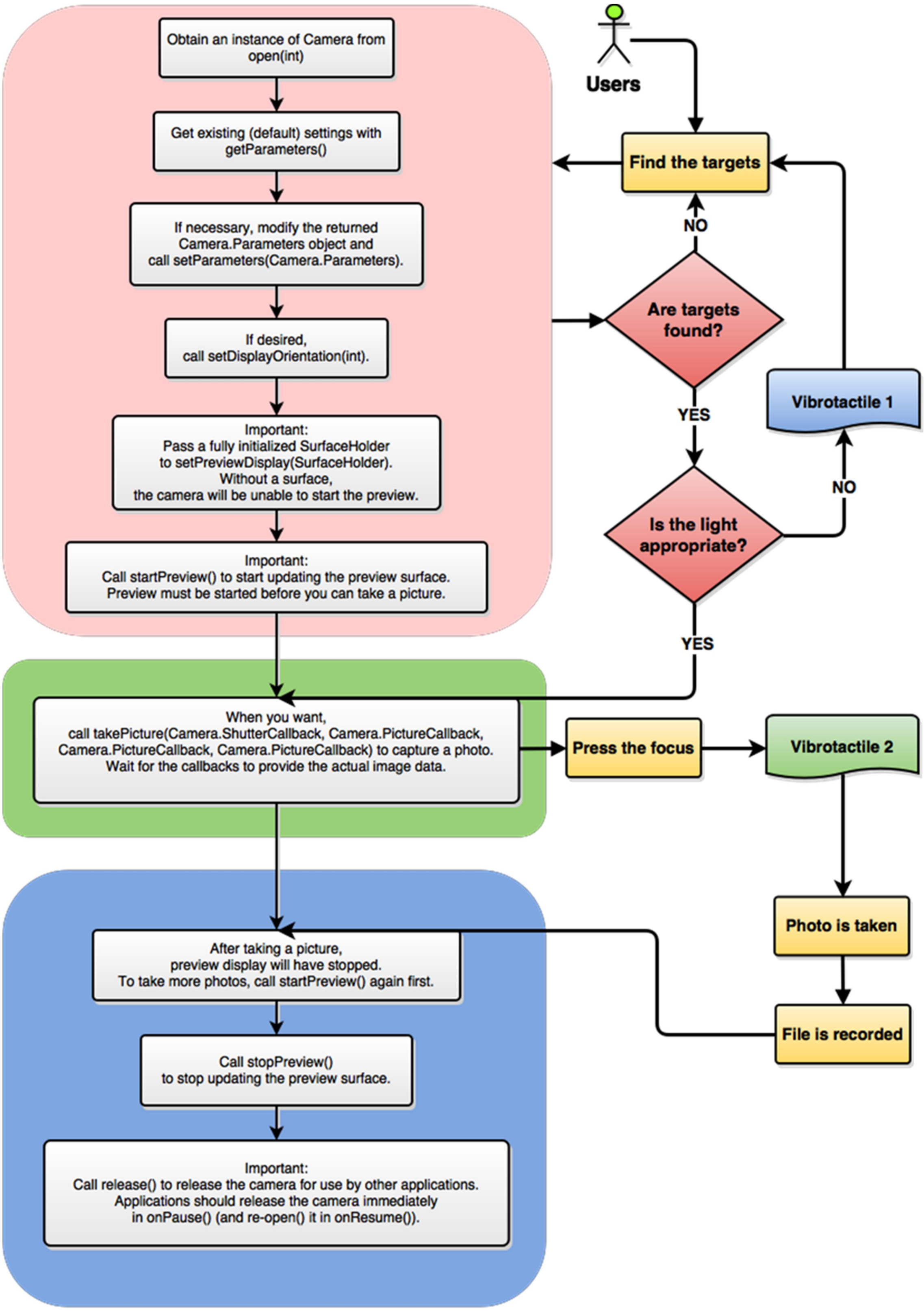

Figure 13. *Flowchart diagram showing how to apply vibrotactile to the camera application for further development*

6. DISCUSSION AND CONCLUSIONS

In this thesis, the studies have shown that haptic technology is becoming more and more important in our everyday life. With the increase in the amount of information coming from our everyday environment to be processed, new vector of nonverbal communication have to be found, haptic technology is one of the tools for these vectors. For mobile phone cameras, the haptic feedback allows users to have a better experience as well as better grasp of their tool. It also significantly improves the way users interact with the mobile phone camera, as well as helps improve the quality of their photos by providing additional information through nonverbal communication process.

However, during the literature review, I have found out that studies concerning haptic technology in mobile phone are not yet as prevailing. Additionally, studies regarding haptic technology in mobile phone have attained more attention over the years. Nonetheless from an investigation, we have seen that studies surrounding haptic technology in mobile phone cameras are still rather limited. The primary explanation for this limitation could be that the combination of haptic technology and mobile phone cameras are still relatively new to the field.

Photography has changed through time as well as human habits that develop around different types of camera from assisting painters and artists, to becoming the art itself. We have learnt that photography has been with human beings as a tool for many purposes; one that we all agreed to is to help remembering our pasts or important moments.

In addition to mobile phone camera in smartphone where haptic feedback could make a different to benefit users, smartphone now provide users with so many customizations, however regardless of varieties, touching screen left and right or pressing a button, if our screen is purely just a flat screen one thing we would miss is the sense of touch, what I meant here is when you touch a button or a keyboard you want to feel that there are buttons or keyboard right where you touch them. Therefore, as you can see in most keyboard application often provide setting where you can customize how you want to feel your keyboard. Despite keyboard and buttons, in many games haptic feedback is playing an important role. For instance, in racing car game, to communicate with players' feelings when they are hitting something or when there are obstacles ahead to make players fully aware of their actions, haptic feedback is very useful and vital in such situation.

In this thesis, I would suggest that vibration can be an interesting feature but in some situation it might generate more difficulties when taking photo because it could make the camera unstable. Vibrotactile on the other hand would be more beneficial especially for when pressing button to focus, users could feel a small sensation notifying that objects are being focused already.

Expectation of users from our studies has shown us time and time again that haptic feedback is needed, and would be appreciated. Therefore in order to utilize this thesis in the future, developers or manufacturers should find the right feedback to each action to ease users while handling mobile phone camera.

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APPENDIX 1: PERMISSION TO RECORD THE INTERVIEW

INFORMED CONSENT
to participate in a research session on ___________________________

I will participate in an interview organized by Tampere University of Technology, Unit of Human-Centered Technology (IHTE) on ____ / ____ / 2011.
The interview is part of a study that aims to ____.

☐ I give my consent for audio recording of this session

☐ I do not give my consent for audio recording of this session

The data gathered during this study session will only be used by the research personnel at IHTE (group at TUT, department of Software Systems), and it will not be given outside.

Any information you give out will be confidential and will be processed anonymously. Results of the study will be reported gathered and they cannot be connected to participants.

Place and date: ______________________________

Participant of the study:	**Research performer:**
Signature of the participant	Signature of researcher
Clarification of signature	Clarification of signature

(Researcher fills)
Identifier of the participant for anonymization: _____________

APPENDIX 2: BACKGROUND QUESTIONNAIRE

1. User Background

1.1 Gender

☐Male ☐Female

1.2 Age Range

☐18-20 ☐21-30 ☐31-40 ☐41-50 ☐51-60 ☐61up

1.3 Profession or study field

____

____

____

1.4 Frequency of using mobile phone camera

☐Daily ☐Weekly ☐Monthly ☐Weekly ☐Occasionally ☐Never

1.5 Types of phone you have owned (present and past, as many as you can remember)

____

____

____

1.6 Do you also own digital camera (If yes, please specify the brand and model)?

☐Yes______________________________ ☐No

1.7 What kind of photo related hobbies do you have?

____

____

____

1.8 Are you familiar with devices that provide a response via sense of touch to user's commands interaction? If yes, which kind

____

____

____

APPENDIX 3: INTERVIEW QUESTIONS

2. User Past Experience

2.1 Do you like to take photos with your phone? (Why/Why not)
2.2 What kind of challenges have you encountered with the phone camera?
2.3 Have you ever encountered situations where taking photos with the phone was difficult?
2.4 What were the reasons for the difficulties?
2.5 Have you ever had any technical problems with the phone camera?
2.6 In your opinion, what is the best photo you took with your phone camera?
2.7 Could you please share the situation and the way of taking photo if it is not indiscreet?

3. User's Photo taking habits

3.1 What types of photos do you usually takes (portraits/landscape/…)?
3.2 Where (in what kinds of situations) do you normally take photo?
Please describe 2-3 typical situations.
3.3 Have you ever taken photos while you are moving (walking, in a car or bus)?
If yes, did you encounter any difficulties in taking photo?
3.4 If you are planning to buy a new phone, which one? Why?
Do the phone camera performances have any influence on your decision?
3.5 Apart from using camera, what are the other applications you are either interested in or are currently using that related to advance techniques of touching?

4. User Needs (Product Characteristics and Ideas)

4.1 How do you consider the phone camera interface at the moment?
4.2 If you could improve your phone camera interface, what would you like to add or remove?
4.3 Do you have any ideas of how haptic feedback could help your photo taking?

APPENDIX 4: HAPTIC TECHNOLOGY IN DIFFERENT DOMAINS

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