TOWARDS A FRAMEWORK FOR EMOTIONAL TACTILE INTERACTION DESIGN

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Abstract. This study aims to explore the possibility of maintaining intuitive behavior patterns and the most natural relationship coming from physical touch between "human" and "object" as interaction behaviors in interaction designs. Such an interaction will convey affection while providing brand new applications and innovative experiences offered by digital technology. "Interactive behavior is natural, but the experience of affection is novel" is the core idea of the interaction design in this study. The study aims to use a familiar artifact in daily life as the main carrier and embed technology in them and activate them, enabling them with sensitive sensing ability. With such an ability, the interaction between "human" and "objects" is thus sensed in a pattern of touch, which itself is affective and interactive. Interactions at the proper time can be provided as feedback, allowing users to experience emotional interaction. Through the analysis of the author's six interaction design projects and experiments over 10 years, the design process and framework for emotional tactile interaction design in using a familiar artifact is proposed.

Keywords. Tactile; Interaction design; Intuitive behavior; Familiar artifact.

1. Background and Objective

In addition to verbal communication, humans communicate using nonverbal methods , such as facial expressions, gestures, and touch. Among these methods, "touch" is a significant way of conveying affection, thus playing an essential role in improving mental and physical health (Field, 2010; Morrison, et.al, 2010; App, et.al, 2011). In daily life, physical contact and touch behavior occur frequently both between "human" and "human" and between "human" and "object." According to research, affective touch can regulate physiological reactions, build up relationships, and alleviate disruptive behavior (Van Erp et.al, 2013, 2015; Burleson, 2007). Hector et al. also suggest in their human-computer interaction study that affective touch can function as a regulator with a positive effect, not only between "human" and "human" but also between "human" and "robot," which is mediated through digital computation (Guthier, 2016). Due to recent progress in technology, human-computer interaction interface design is shifting from a graphical user interface (GUI) to a more natural and human-centric

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natural user interface (NUI). NUI focuses more on natural human behaviors, such as touch, body gesture recognition, and language recognition.

The research literature reveals that the focus of interaction design is shifting toward a more intuitive NUI design, and how to turn the behavior patterns obtained from observing user behavior into a more adaptive interaction interface is this study's major focus. Some studies have explored how to understand user behavior through "observation," with user-centered design in mind and have successfully applied it during the design process. They use "observation" as the primary design method in the course of design and propose its value (Kang, 2013). The study by Kang and Suto proposed a theoretical model of ADT design, indicating the close relationship among designers, users, and artifacts. Such a relationship shows that the designer's observation of user behavior must be based on his/her behavior pattern and the physical laws applicable to the artifact he/she contacts. Thus user experience emphasizes his/her behavior of "human" and "object" or physical properties and the inseparable, interactive behavior relationship between the two.

As a result, technologies such as Ubiquitous Computing, Mobile Computing, Sensors and Actuators, Internet of Things, Ambient Intelligence (Aml), and Affective Computing have been adopted to meet the more natural and human-centric needs of interactive design. There are many interactive behaviors and patterns in human events. However, despite these proven technologies, the interaction interface or devices for the current interaction designs are still presented in a way that depends largely on existing input interfaces offered by the digital interactive products, including touch screens, keyboard and mouse, joysticks, and button control devices. Interactive behaviors are still based on the operation behavior patterns provided by such digital devices, which raises the learning threshold for operation. Therefore, this study aims to explore the possibility of maintaining intuitive behavior patterns and the most natural relationship coming from physical touch between "human" and "object" as interaction behaviors in interaction designs. Such an interaction will convey affection while providing novel applications and innovative experience offered by digital technology. "Interactive behavior is natural, but the experience of affection is novel" is the core idea of the interaction design in this study. The study aims to use a familiar artifact in daily life as the main carrier and embed technology in it and activate it, enabling it with sensitive sensing ability. With such an ability, the interaction between "human" and "objects" is thus sensed in a pattern of touch, which itself is affective and interactive. Interactions at the proper time can be provided as feedback, allowing users to experience emotional interaction. Through analysis of the author's six interaction design projects and design experiments spanning ten years, the design process and framework for emotional tactile interaction design in using a familiar artifact is proposed.

2. Research Method and Analysis

Based on the study objective, user behavior is explored through observation, whereas creativity is applied in designing the solution. With the research method called AEIOU, which is often used in user experience studies, the author validated and analyzed six interaction design projects (Lim, 2015, 2016, 2018, 2019)

conducted during the period from 2010 to 2020. The six interaction design projects in this study are divided into two categories: interaction design for intergenerational care and interactive space design. The pain points, design solutions, and introductions to the technologies employed for each project are shown in Tables 1 & 2.

Table 1. Interaction design for intergenerational care.

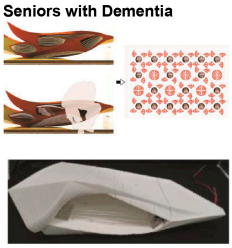
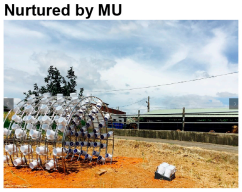
Project Name	Paint Point (P) - Solution(S)	Technology
1. **2019** **Pillow Fight** 	(P). Through observation, the author's mother in the terminal phase of cancer was found to be less and less capable of playing with grandchildren. The experiences that remained most intimate to mother were only holding a pillow sitting on the wheelchair or sitting on the bed side, watching her grandchildren playing tablet games by themselves. How can more interaction be created between these two generations in an intuitive way? (S). By combining the familiar objects dear to them, the pillow and computer games played by the grandchildren, grandparents can enjoy intimate family relationships anytime through intuitive interaction pattern (touching).	•Capacitive touch sensors design (conductive thread, fabric) •PCB design •Bluetooth BLE •App games •Digital fabrication (laser cut, 3D print) •Mass production
2. **2019** **Wonder Corner** 	(P). The living room is the space where family members spend time together most often. Is it possible for the family members to physically interact more intimately with the objects in such a space, instead of playing with a cell phone, with head down? (S). By connecting the sofa, cushions, TV, stereo, lights, and floor in the living room through IoT technology, the author built an interaction pattern that allows family members to enjoy entertainment together. Sitting on a sofa, holding a cushion, and sitting on the floor could be the inputs to the game. Lights, TV, and stereo then can be the audio and video outputs of the game. In the design, the most natural way of contact between body and object can be used to replace an electronic game's joystick or controller. The information of activities happening in the space is collected through the transmission of messages by the objects endowed with the ability to sense.	•Capacitive touch sensors design (conductive thread) •PCB design •Bluetooth BLE •MQTT (IoT) •App games •Parametric design •Digital fabrication (laser cut, 3D print)
3. **2010** **Interactive Space Design for Seniors with Dementia** 	(P). Why are the technology products for seniors only designed with focus on the function, mainly as an assistive device? Shouldn't we care about the psychological needs of the seniors whose only hope is just a little bit more company? How can we enable the children of parents with dementia to pay more attention to their parents, who keep waiting at home most of the time for children's company? (S). We designed an adaptive shoe rack and an adaptive wall in the living room. When the children return home, they can take off the shoes and put them in the adaptive shoe rack. The adaptive wall will then immediately show the pictures that include them and the parents, prompting the shared memory, and play the music that both enjoy. This will not only bring up the children's memory of their parents with dementia but also, through it, reminds them of their need for more caring.	•Arduino (IR sensors, motors, LED) •Digital fabrication (laser cut, 3D print)

Table 2. Interactive space design.

Project Name	Paint Point (P) - Solution(S)	Technology
1. **2015** **HHSS Adaptive Wall** (A soft illuminating wall that detects heartbeat)  	(P). How can we allow the physical space to reflect the heart rates of those in action in the space? How can we enable the space to visualize the physiological information of those who are experiencing such space through dynamic feedback from the structure? How can we allow the space to feel people's heartbeats? (S). We designed a two-meter-long tunnel in which the spatial structure pulses mechanically in a rhythm following the heart rates of the people who act in it. By illuminating a piece of soft cloth, the skin layer of such a spatial structure reacts with feedback to such a rhythmic pulse. Those who experience must put on headphones first when entering the entry and listen to their favorite music. They then enter the tunnel to experience the visualization of their heart rates. The soft illuminating cloth also changes its color and presentation following a change in the rhythmic pulse. The design receives the heart rates of the visitors most naturally with a receiver hidden in the headphone. The heart rate is then transmitted via Bluetooth connection to the control end of the spatial structure, allowing the motor on the structure to operate.	•EL fabric •Arduino (heart sensors, motors, speakers) •Bluetooth •Parametric design •Digital fabrication (laser cut)
2. **2015** **Shape, Cloud** 	(P). How to let visitors interact with, feel, and enjoy the natural elements, namely, cloud, wind, thunder, and rain, through an interactive device. (S). We designed a cloud and a fan for visitors to blow air. "Invisible wind" serves as an input whereas "visible cloud" is an output. When visitors blow air together, thunder will come from a big cloud; a muffled thunder will be heard if blowing continues; louder thunder will be heard with further blowing; and finally, it begins to rain when the maximum value is reached. Children can work with parents and have fun interactively experiencing changes in the natural phenomena.	•Arduino (sound sensors, LEDs, speakers) •Bluetooth •Parametric design •Digital fabrication (laser cut)
3. **2017** **The Mystic Land Nurtured by MU**  	(P). Following a site survey, a cattle farm was found next to the site with a flight path above it. The site was a big, open field without any obstructions; the space was bright and shiny, with distinct light and shadow. We consider how to let the visitors or children coming to feed the cattle in the farm experience simultaneously, on-site, the spatial devices that are related to cattle, hay, milk, and life. (S). The theme of the design, the Mystic Land Nurtured by MU, is conceived from observing the status quo of the site. Nearly 200 milk powder cans that author's son has drunk for five years have been used and made into a milk-bottle castle shaped like a round hay bale. Give it to author's son as a gift and tell him that this is the secret place that nurtures him. On the cap of the can, make transparent stickers with silhouettes showing the growths of the author's son in different stages of life. All the silhouettes appear on the ground under the sun. Milk powder cans and the structure are secured by the parts made with 3D printing. They sway as the wind blows from different angles. Cowbells are hidden in the milk bottles. The cowbells of the whole structure will ring when the wind is strong.	•Parametric design •Digital fabrication (laser cut, 3D print)

2.1. "PROBLEM FINDING" METHOD AND PROCESS IN EARLY PHASE OF THE DESIGN

The AEIOU method emphasizes observations in five dimensions: activity, environment, interaction, object, and user. These observations will serve as analysis factors used to understand user-relevant humans, activities, and objects in each design project. Table 3 shows the AEIOU factor analysis performed by observing pain points in the design project. From the empirical analyses of these design projects, this study concludes the pain points in the early phase of the design or "problem finding" method and process. Based on the emotional orientation, the author observed the pain points in the life event and then found the familiar pattern of interaction from human, activities, and object observed. Finally the author sorted out the familiar life object that creates a relationship with the human in these interactions. The major process is shown in Figure 1. The familiar artifacts sorted out from activities will serve as the main interactive carrier that will subsequently enter into a design solution.

Table 3. AEIOU factor analysis of each design project .

Project Name	**U**ser	**A**ctivity (paint point)	**E**nvironment	**O**bject (familiar artifact)	Interaction
1. **2019 Pillow Fight**	•Grandmother •Grandchild	Grandmother was unable to accompany her grandchild due to illness, so she could only watch her grandchild play by himself.	Living room	•Pillow •Wheelchair •Bed •Tablet	•(touch) Grandmother holding the pillow •(touch, sight) Grandmother sitting on the wheelchair and watching her grandchildren playing tablet games by themselves. •(touch) Grandmother sitting on the bed side •(touch) Grandchild playing tablet on the floor
2. **2019 Wonder Corner**	•Family members	The whole family gathered together but looking at their respective phones/tablets.	Living room	•Mobile phone •Tablet •Pillow/Cushion •Sofa •Floor •TV •Lamp	•(touch, sight) Adults sitting on the sofa and playing their mobile phones •(touch, sight) Adults sitting on the sofa, holding the cushions and all become phubbers. •(touch, sight, hear) Children sitting on the floor and playing tablet games. •(sight, hear) The TV is on and sometimes someone looks up and watches.
3. **2010 Interactive Space Design for Patients with Dementia**	•Seniors •Child	The child who goes home every day no longer cares about the elder with dementia who waits for him to come home every day.	Home	•Shoe rack •Entrance Door	•(touch) Child takes off the shoes and puts into the shoe rack •(touch, sight) Seniors with Dementia sitting and looking at the entrance door, waiting for their children come home.
4. **2015 HHSS Adaptive Wall** (A soft illuminating wall that detects hear beat)	•Visitors (All age groups)	How to make the tunnel respond to the physiological state of people who walk into the space? Can the space feel like people are alive?	Exhibition Hall	•Tunnel wall •Earmuff headphones	•(touch, hear) Wear headphones to listen to music •(touch, sight) Walk through the tunnel, and the wall will give feedback in time.
5. **2015 Shape, Cloud**	•Visitors (All age groups)	How to represent natural phenomena in a fun and interactive way. Natural phenomena related to a cloud: wind, thunder, rain.	Exhibition Hall	•Windmill •Cloud	•(touch) Blow •(hear) Thunder in the distance before the wind was blowing •(hear) The closer the thunder, the louder •(sight, listening) raining
6. **2017 The Mystic Land Nurtured by MU**	•Visitors (All age groups)	How to present the birth of life next to the cattle farm?	Outdoor exhibition	•Milk powder can •Bells	•(hear) The sound of bells in the farm • (hear) The sound of wind blowing •(sight) strong sunlight

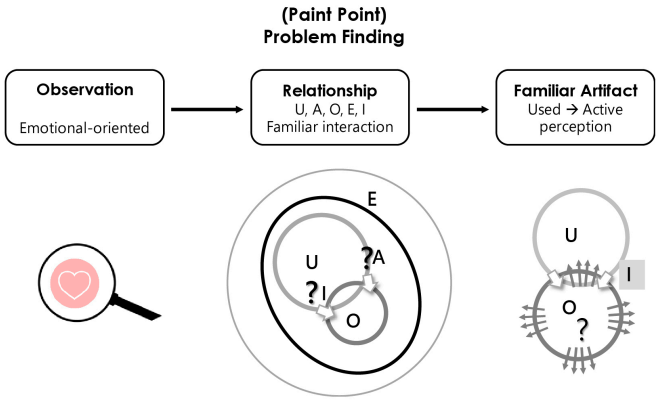


Figure 1. The "problem finding" method and process in the early phase of the design.

2.2. "PROBLEM SOLVING" METHOD AND PROCESS IN THE DESIGN PROCESS

The findings and phenomenon based on the observations from AEIOU in the previous phase will be applied effectively in the design process as operating elements for the creative concept. The relationship between Users and Objects, i.e., Interaction, concluded from the "Problem Finding" stage in the early phase of design will continue to serve as a familiar interaction pattern for the design concept. The identified object, especially the familiar artifact in life, then serves as the author's major design carrier or interaction interface in each design project. These familiar artifacts will be redefined for their roles in the design process. Their roles will change from the original status of passive usage to activated objects with active perceiving ability by using ubiquitous computing or the method of how the sensing technology is hidden.

Figure 2 (a, b, c, d, e, f) shows how to make a familiar object the interaction carrier in each interaction design project and how to maintain the object's familiar interactive behavior and pattern designated by the design concept. Because this phase includes the implementation and modification process from abstract concept to the material object, it is, therefore, one with the major steps and processes in which the manufacturing technology and application are validated in the transformation from concept to tactile object. Most of the design projects in this study are for prototype design and development in the design process. However, "Pillow Fight" has undergone many cycles of V-validation (application validation) and has entered commercialization; it has also been mass-produced in small volumes successfully and finally sold to institutions for seniors. Based on the design process and step analyses for solving all project issues, this study has concluded a framework of method and process for "problem solving" in the design process, as shown in Figure 3.

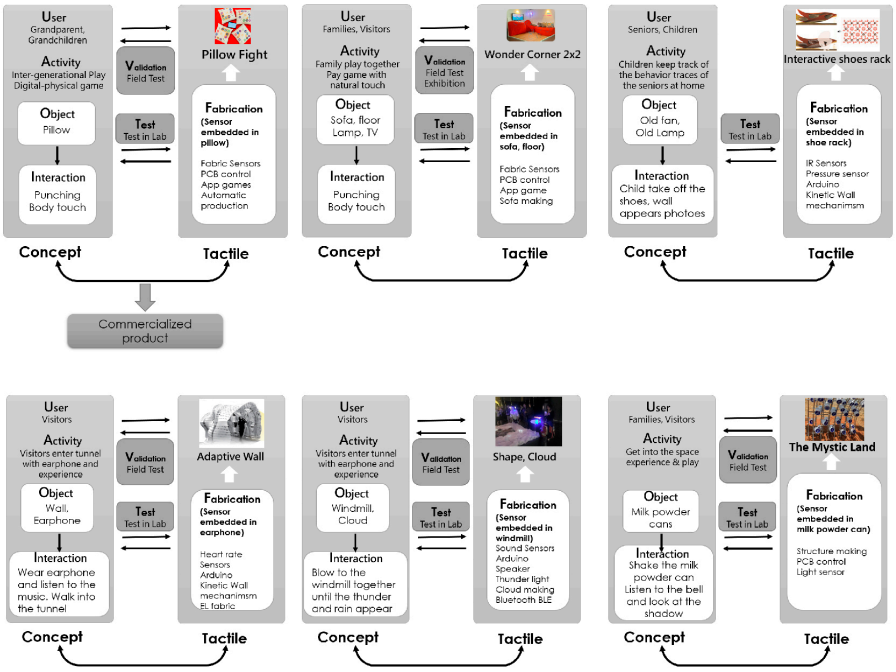


Figure 2. The process making a familiar object the interaction carrier in each interaction design project.

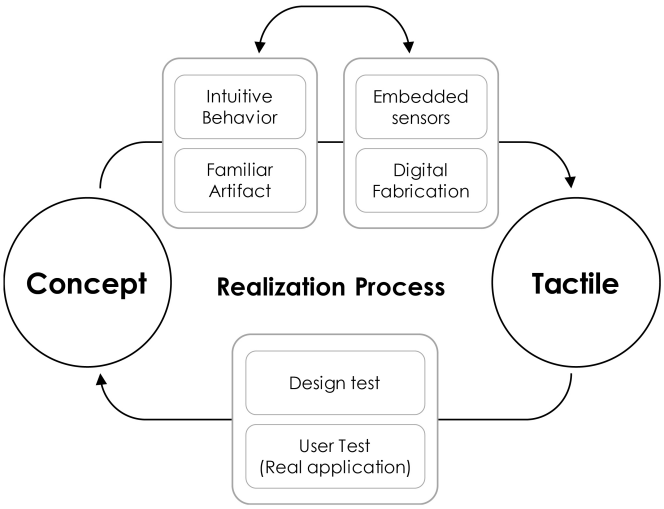


Figure 3. The “problem solving” method and process in the design process.

2.3. "PROBLEM SOLVING" METHOD AND PROCESS IN THE DESIGN RESULT

As a follow-up from the design method and process analysis for the eight design projects conducted by the author over a decade, this section will explore the interaction solving and its interaction characteristics sought for the familiar artifact in each project's design result, as shown in Table 4. There are five analysis factors: Familiar Artifact, Activated, Method, Intuitive behavior and new experience.

Table 4. Interaction solving and its interaction characteristics sought for familiar artifacts.

Project Name	Familiar Artifact	Activated Perception	Method	Intuitive behavior	New experience
1. **2019 Pillow Fight**	•Pillow	Sense by users' punching and touching	Make the original material of the object into sensor cotton + conductive thread (Developed and manufactured sensing element. The sensing layer is hidden in the cotton, then sewn into a pillow core.)	Punch pillow Touch pillow	**Intergenerational care, parent-child entertainment** Play games with mobile App
2. **2019 Wonder Corner**	•Sofa •Floor •Lamp	Sense by users' punching and touching	Make the original material of the object into sensor Original sofa fabric+ conductive fiber (Developed and manufactured sensing element. The sensing layer is hidden in the cotton, then sewn into a sofa cover.)	Touch sofa Touch floor	**Parent-child entertainment** Play games with mobile App
3. **2010 Interactive Space Design for Patients with Dementia**	•Shoes rack	Can sense children coming back home	**Redesigned** shoe rack combined with interactive control. To combine sensing and control, redesigned a new shoe cabinet (made into a sensor element and dynamic mechanism hidden in the shoe cabinet) At the same time, the interactive wall is also designed to present a photo.	Changing shoes when children go back home.	**Intergenerational care** Combined with interactive sensor to remind children to care for their demented elders when they come back home.
4. **2015 HHSS Adaptive Wall** (A soft illuminating wall that detects heartbeat)	•Headphone •Wall	Can sense the heartbeat of visitors who listen to music with headphones in the space	**Redesign** space structure combined with interactive control To combine sensing and control, the tunnel of a free-form wooden structure similar to blood vessels was redesigned. (Sensor and dynamic mechanisms were made to be hidden in space.)	listening to music with headphone while walking through the tunnel.	**Physiological Information Visualization** Combined with dynamic soft wall dynamic changes
5. **2015 Shape, Cloud**	•Wind mill •Cloud	Can sense the volume of the air that visitors blow out	**Reproduce** cloud shape structure and combine with interactive control. To combine the sensing and control, natural phenomenon, thunder, lightning were reproduced by the feedback of LED and sound control.	parents and children work together to blow at the windmill.	**Parent-child entertainment** Natural phenomenon reproduction, combined with natural action entertainment experience
6. **2017 The Mystic Land Nurtured by MU**	•Milk powder cans •Bells	Can sense the touch and shock by visitors or wind	**Redesign** space structure and combined with interactive control. To combine the sensing and control, sensors embedded and hidden in the milk powder cans.	Chidren hiding into the space and playing with the cans by shaking, listen to the bell ring.	**Parent-child entertainment** Natural phenomenon reproduction, combined with natural action entertainment experience

3. RESEARCH RESULTS

Based on the analysis shown in Table 4, this study completes a design process that starts from the observation AEIOU method and focuses on intuitive interaction behavior design by activating familiar objects in daily life to become input sensor devices. Through analysis of the six design projects completed by the author during the last decade, certain characteristics and methods can be identified as follows (Figure 4):

1. "Hidden technology " appears in interactive behavior and persists in maintaining original intuitive behavior patterns.

2. Three methods of how "Perceiving Object" activates original object into one with perceiving functions:

- M1: Use raw material and make a component into one with a sensing function
- M2: Combine original object with interactive controls
- M3: Redesign show rack by combining interactive controls

The comparison of these three methods is shown in Table 5:

Table 5. The comparison of three methods of activated original object to become the sensors.

Method	Fabrication Time	Making Difficulty	Familiar to Users
M1	Long	High	High
M2	Middle	Middle	Middle
M3	Short	Middle	Low

3. The feedback mechanism is based on visual and auditory senses. Feedback mechanism and actuation object for the intergenerational caring design process: APP provided to the younger generation, dynamic (original object changing from passive dynamic to active variation). The feedback mechanism of the interactive space design project is based on visual and auditory senses.

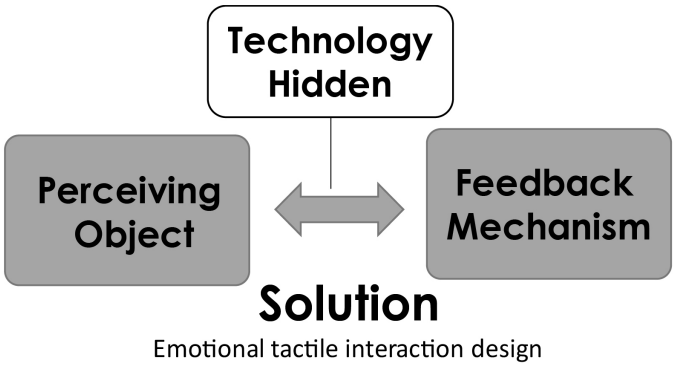


Figure 4. "Solution" Emotional tactile interaction design process.

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