

Understanding Expressions of Internet of Things

Kuo Chun, Tseng*, Rung Huei, Liang **

* *Department of Industrial and Commercial Design, National Taiwan University of Science and Technology, Taipei, Taiwan, jasan1105@gmail.com*

** *Department of Industrial and Commercial Design, National Taiwan University of Science and Technology, Taipei, Taiwan, jazzliang@yahoo.com.tw*

Abstract: A recent surge of research on Internet of Things (IoT) has given people new opportunities and challenges. Unfortunately, little research has been done on conceptual framework, which is a crucial aspect to envision IoT design. We found that designers usually felt helpless when designing smart objects in contrast to traditional ones and needed more resources for potential expressions of interactive embodiment with this new technology. Moreover, it appears to be unrealistic to expect the designer to follow the programming thinking and theory of MEMS (Micro Electro Mechanical Systems) field. Therefore, instead of focusing on exploring the technology, this paper proposes an analytical framing and investigates interactive expressions of embodiment on smart objects that help designers understand and handle the technology as design material to design smart objects during the coming era of IoT.

To achieve this goal, first we conceptualize an IoT artifact as an object that has four capabilities and provide a clear framework for understanding a thing and multiple things over time and space in ecology of IoT things powered by a cloud-based mechanism. Second, we show the analytical results of three categories: smart things and design agenda over cloud in respect of time and space. Third, drawing on the taxonomy of embodiment in tangible interfaces by Fishkin K. P., we demonstrate possible ways of embodiment in a thing and illustrate possible ways of interaction between two things in the framework of IoT. In this way, more embodiments of objects are expanded. Finally, we discuss the functions of various applications to classify them in relation to IoT works including commercial products and some reflective works that help designers understand the application possibilities of current IoT works.

Key words: Internet of Things, Embodiment, Interaction Design

1. Introduction

The Internet of Things (IoT) provides a vision that refers to a network embedding every object into our daily lives with uniquely traceable identification and virtual representation. Obviously, the complete tracking system on cloud is an important part of it. In 1999, this catchphrase was first used by Kevin Ashton [3] who was a cofounder and executive director of the Auto-ID Center. After that, the ITU (International Telecommunication Union) published the report “The Internet of Things” officially in 2005. Hereby, ITU claimed that information and communication technologies (ICTs) has a new dimension added to the world from anytime, anyplace connectivity for anyone and we will now have connectivity for anything, see Figure 1.

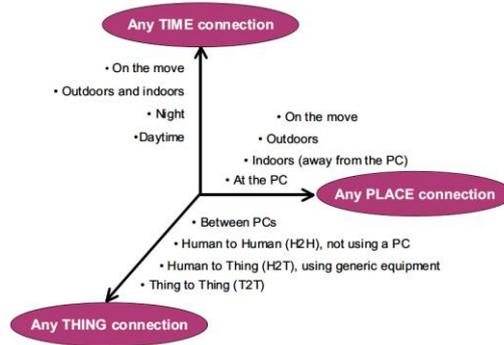


Figure.1 A new dimension added to the world from anytime, anyplace connectivity for anyone [3]

Soon, with maturing technology of Radio-Frequency Identification (RFID), Wireless Sensor Network (WSN), Embedded Intelligence, Nanotechnology and Micro Electro Mechanical Systems (MEMS), numerous predictions of the IoT are coming true. All things could communicate and interact to each other at anytime and anyplace. Furthermore, according to the statics by Cisco Internet Business Solutions Group (IBSG), they are of the opinion that when the numbers of connected devices are more than the world populations, it's the starting point of the era of the IoT, which indicates the year of 2008 to 2009. Eventually, they predict that the numbers of connected devices will be almost four times comparing to the world populations in 2015, see Figure 2.

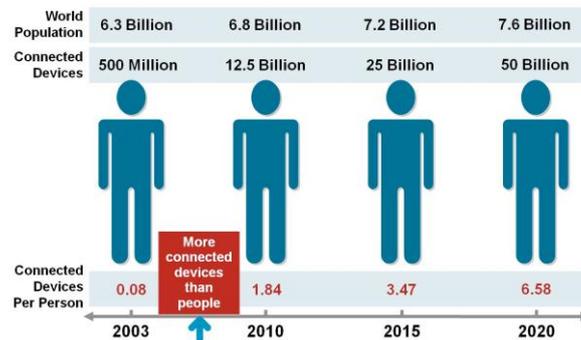


Figure.2 The statics result of world populations and connected devices [11]

Accordingly, we can imagine that if every kind of animals, plants and objects such as shoes are connected to the IoT in the future, they will make impossible phenomena come true and create more possible interactive ways between each other. Poetically thinking, when many devices with sensors and actuators are embedded in the planet, imagines that we could feel the heartbeat of the earth.

Above all, the notion of IoT not only causes a tremendous revolution in ICTs but also generates diverse forms of interaction in our daily lives. Notwithstanding, we must conceive that we are not only approaching such a world but on its doorstep [40]. However, in ideating IoT design, we found that designers usually felt helpless because of their unfamiliarity with new technology in IoT such as wireless communication and Radio frequency Identification (RFID). This inhibits them from contributing their creativity and design skills to the interaction design community.

Moreover, it is unrealistic to expect designers to follow the expertise of program coding and theory of MEMS (Micro Electro Mechanical Systems). Therefore, instead of focusing on how to employ the technology, this paper emphasizes what IoT could be by proposing a clear framework that helps designers regard the technology as

design material [24] to make ideation while designing IoT objects. Furthermore, we expect that designers are inspired to create better functional products in terms of aesthetic experiences [18] and expressive interactions by understanding the expression of IoT.

2. The role of IoT in interaction design

2.1 Internet and cloud computing

With the maturation of Internet technology, people are no longer limited to the physical space when performing tasks. Furthermore, by developing cloud technology such as online storage, data could be stored for a long time and accumulated for some period. In a nutshell, data displaying over space and reproducing over time are very common with various forms. These phenomena show a trend of IoT, and there will be more design space in designing interaction over space and time. By doing so, Figure 3 shows that we could easily find that there are more design possibilities in zone II, III and IV with different combinations of time and space.

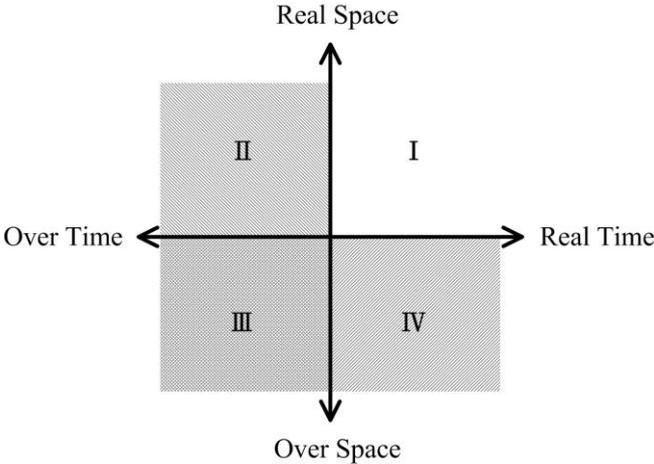


Figure.3 New design area and possibilities of IoT in three zones: II, III and IV

2.2 Toward a framework of IoT

In order to knowing more possibilities of interaction design in the coming era of IoT, first, we need a framework for understanding it. Therefore, we make our effort to construct the framework as follows. From the perspective of physical computing [25], an object has three parts: sensors, computation and actuators. Besides, in the cloud-based mechanism, network is taken for granted as a basic capability of an IoT object. In this way, we know that an object of IoT is regarded as a weighted combination of four capabilities provided by sensors, computation, network, and actuators. When space changes and time goes by, these four capabilities could be divided and distributed to the cloud by novel technology as Figure 4 shows.

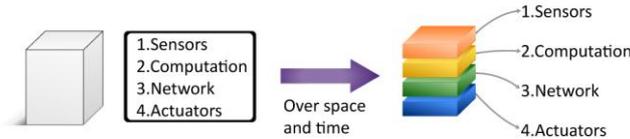


Figure.4 The illustration of four capabilities, separated over space and time

In addition, we wonder what it will be if these four capabilities are distributed to the cloud? We could imagine that some capabilities of an object are provided from the cloud and contributed by other objects. In another word, an object of IoT is able to have different capabilities through the cloud, see Figure 5.

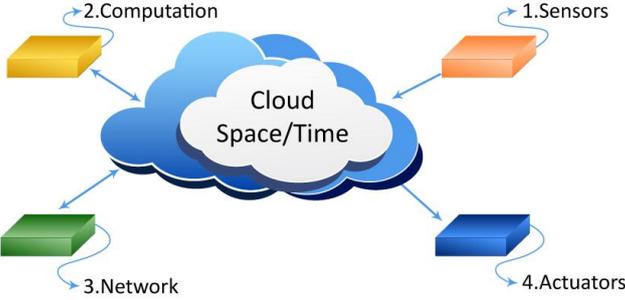


Figure.5 The illustration of "one thing" in the cloud

In a whole, in the structure of IoT, capabilities of every object are possibly contributed from different objects. For instance, the computation capability is provided by an object through the cloud and actuator capability is provided by another object, see Figure 6.

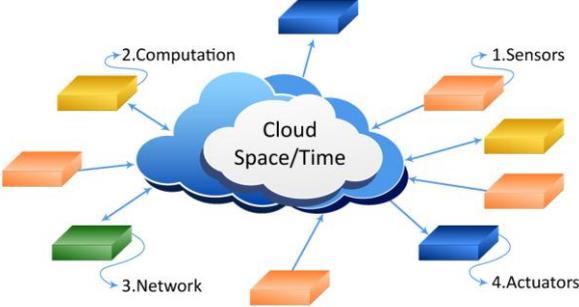


Figure.6 The complexity of "multiple things" in the cloud over time and space

2.3 Understanding IoT products and a design agenda

We use this framework to understand IoT products. In this section, we take Poken [26], Ambient Orb [1] and slow technology [14] as examples to analyze them over cloud.

Considering real time and over time as well as real space and over space, there will be sixteen different permutation results in Table 1. For instance, the sensor capability of Poken is real space and real time. However, the network capability of Ambient Orb is real space and real time while Poken is over space and over time. Meanwhile, when the actuators of an interactive system are over time, it also refers to the design agenda called slow technology.

Table1. The analyses of three objects and one design agenda related to our taxonomy over time and space

IOT over Cloud	Sensors	Computation	Networks	Actuators
Real time	Ambient Orb			
Real Space	Poken			
Over time		Poken		Slow Technology
Over Space	Ambient Orb			

To sum up, from this framework, we know that an object in IoT becomes a mashup of sensors, computation, network and actuators through cloud technology. Besides, user experience could be interwoven to a great extent. Eventually, interaction should be designed as space and time coupled embodiment.

3. Embodiment of Things

From the framework described above, we know an IoT object is a mashup of four capabilities under cloud technology. Furthermore, designers should consider space and time coupled embodiment of interaction. In this way, interaction design would be unfolded to a new dimension by means of cloud technology. For sake of understanding the interaction between objects, first, we need to realize the embodiment of them. Thus, according to the taxonomy for an analysis of tangible interfaces [12], there are four levels of embodiment characteristics: Full, Nearby, Environmental and Distant, which we denoted in a vector as (F, N, E, D) in our study. From now on, we use Figure 7 to represent them and detail explanations are as follows: (1) Full- The output device is the input device, eg: Sony Gummi [29], Platypus amoeba [9]. (2) Nearby- The output takes place near the input object, eg: MEMOiCON [7]. (3) Environmental- The output is around the user, eg: scent and audio. (4) Distant- The output is over there, another room, remote, eg: Nabaztag [21].

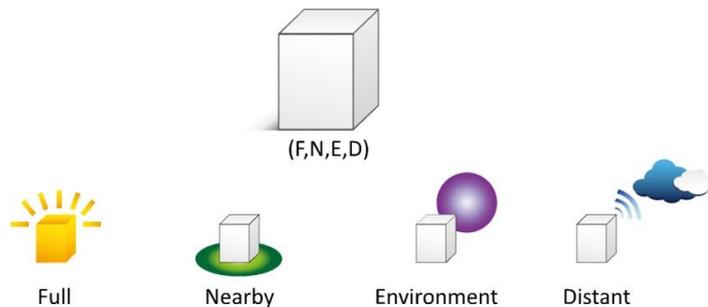


Figure7. The icons of embodiment of things

On account of this we can find that a thing could have multiple embodiments of interaction, such as Full plus Environment. As a result, we know that there are sixteen ways of embodiment in a thing, see Figure 8.

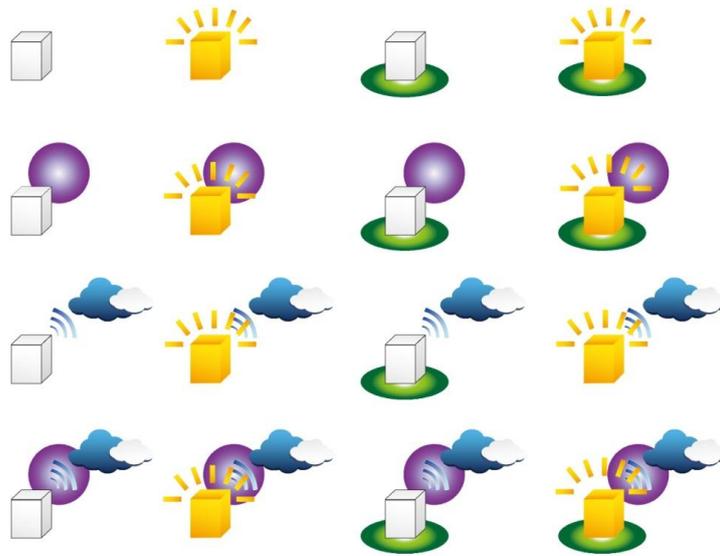


Figure8. Sixteen ways of embodiment in a thing

Accordingly, following the above rule, Figure 9 shows that we could predict that there are 256 interaction ways of embodiment between two things.

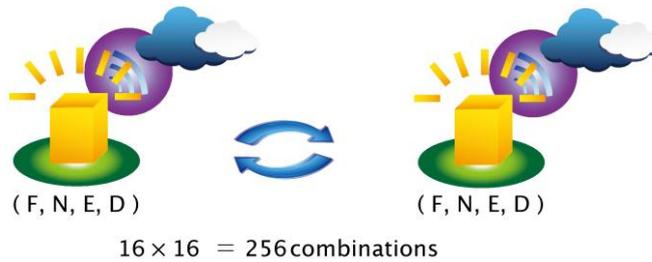


Figure9. 256 Interaction ways of embodiment between two things

Taking Nabaztag for example, when tagging an object in place A, it will light (F=1) and make beep sounds (E=1). By this time, the message passes through Internet to the object in place B and then lights immediately (D=1), see Figure 10.

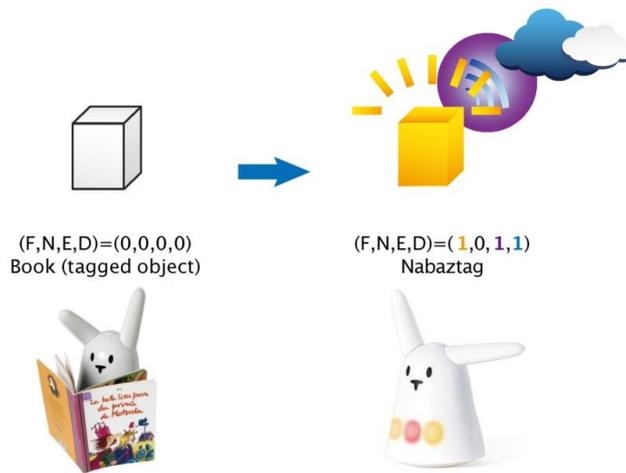


Figure10. Parameters indicating embodiments of two things' interaction: Nabaztag

Moreover, Poken is an IoT product that when two Poken objects touch each other, the personal data will exchange while LEDs getting bright (F=1), see Figure 11.

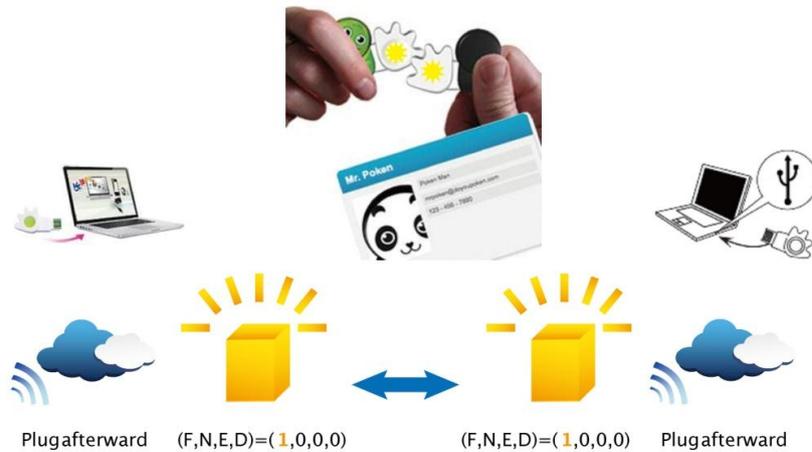


Figure11. Parameters indicating embodiment of two things' interaction: Poken

Although the analysis of interaction between object and object is described above, with the increasing maturity of IoT technology and realization of interconnecting every object, there is not only one way of interaction embodiment in real time and space, but also various ways to discuss when considering over time and space. As we have said, interaction should be designed as space and time coupled embodiment ultimately.

4. Seven design patterns of IoT

In this section, we present an overview of IoT design products and sort out seven design patterns. In this way, we want to provide designers with further understanding of the expressions of IoT works and inspiration of design thinking by these seven design patterns of IoT.

4.1 Pattern 1 (Collective Activities): *IoT could be designed as artifacts that support collective activities in a certain group who are connected and aware of each other in terms of activity records ranging from immediate to long-term usage.*

There are many products and prototypes of this pattern, such as Wattson [39], Nike+ [22], Social Radio & Social Clock [16], Kindle [17], and Scan Toaster [28], etc. see Figure 12.

Taking Wattson and Nike+ for detail description, Wattson and Nike+ are devices that monitor the energy usage and track pace and distance respectively. Wattson shows how much power usage and money when keeping the appliances working. Nike+ records runners' pace, distance and calories burned. The most fascinating is that they are able to compile data and visualize them for a long time. In this way, users could compare the energy usage to that of last month or year and know the routes they run respectively. Besides, users are encouraged by competing with other users to change their behaviors such as turning off appliances after use to save more energy and jogging every day.



Figure12. Works of IoT enabling “Collective Activities”

4.2 Pattern 2 (Connectedness): *IoT could support social connectedness by transferring a social status to an embodiment of actuators over space.*

There are products and prototypes of this pattern, such as Presence Lamp [15], Memory Bricolage Table [43], Lover’s Cup [19] and SnowGlobe [38], etc. see Figure 13.

Lover’s cup shares the feeling of drinking between lovers when they are separated in different places. When one lover is drinking, the other lover’s cup will glow to hint the presence of the lover. Furthermore, they glow at the same time to celebrate like virtual kiss when couple drinks in the meanwhile. SnowGlobe is like a presence lamp which displays light and shows snow fluttering when the other globe sensing movements. The amount of movement influences the intensity of lighting and fluttering.

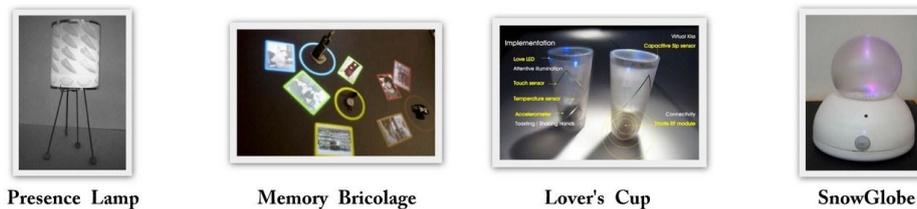


Figure13. Works of IOT belonging to “Connectedness”

4.3 Pattern 3 (Tracking & Logging): *IoT could be designed to provide the functionality of tracking and logging in services and applications.*

This pattern includes products and prototypes such as SenseAware [30], Nokia Sports Tracker [23], Tower Bridge Twitter [36], etc. see Figure 14.

Taking SenseAware and Nokia Sports Tracker for examples, SenseAware and Nokia Sports Tracker provide services of tracking wherein one reports near real-time data of customer’s shipments and the other tracks users’ progress and activities while moving from A to B, such as walking, running, cycling and driving.



Figure14. Works of IoT providing tracking and logging.

4.4 Pattern 4 (Awareness): *IoT could be designed with an emphasis on supporting awareness of contexts over space.*

This pattern includes products and prototypes such as Ambient Orb, Ambient Umbrella [2], TomTom Go [34], and Chumby [8], etc. see Figure 15.

The development of Ambient Devices intends to integrate much information. It connects different channels and lights or displays in different patterns to indicate a specific situation for reminding users. Taking Ambient Orb for example, it could track stock average and glow in green, red and yellow color to indicate market movement of up, down and calm respectively. If an umbrella, Ambient Umbrella, connects to the channel of local weather data, users could know whether it will rain or snow in the forecast by the light patterns of its handle. In other words, it is able to indicate warning information of rain, thunderstorms, drizzle or snow by illuminating different light patterns.



Figure15. Products of IoT belonging to “Awareness”

4.5 Pattern 5 (Social Interaction): *IoT could be designed as personal portable devices that facilitate embodied social interaction in our everyday settings.*

In this design pattern, it focuses on improving embodied social interaction. Poken is an interesting instance. Users take these products to exchange information of social business card with a simple touch. Besides, these objects could be viewed as the bridge between not only digital and real worlds but also front and backward stages of individuals. They seem like instant ice breakers and conversation starters which encourage people to change their contact information and provide memorable experience of interaction. Besides, Social Mutator [32] is a social game consisting of physical products and digital creatures which mutate once people connect with each other. Another prototype of this pattern is BodyBug [4] see Figure 16.



Figure16. Works of IOT facilitating “Social Interaction”

4.6 Pattern 6 (Proximity Triggered Interaction): *IoT could create interactions based on Near Field communication.*

Taking Mir:ror [20] and Nabaztag for example, they could detect objects embedded with RFID when users offer the corresponding items, such as ztamp:s, Nano:ztag's, and some specific everyday objects. When detecting

the objects, it will trigger pre-programmed actions on actuator like a computer, TV or other devices. For example, Mir:ror reads the news aloud when a user waves a stamped coffee mug; Nabaztag reads story books and Skål [31] plays a sequence from the Moomin cartoon where physical Moomin character is featured. Another example of this pattern is Touchatag [35] see Figure 17.



Figure17. Works of IoT belonging to “Proximity Triggered Interaction”

4.7 Pattern 7 (Something Crossing): *A simple everyday object with a shadow, a traceable ID on internet, could be an example of IoT to support crossing and exchanging in a social setting over space and time.*

This pattern is another kind of interesting project of IoT called Something Crossing. As the name suggests, these projects focus on something passing to another across places, such as books, Discs and Postcards. For this purpose, every object has a tag with a unique ID number to trace when users log to the web rather than reading an embedded RFID tag. With archival and tracking system, people are encouraged to visit it on website, log and update the information of objects such as where they have been and when. By doing so, the history of an object is created over time.

As mentioned above, every object is traceable through updating information and displaying it on website. Therefore, the combination of objects and the tracking system makes the project work completely rather than a physical object itself. On the whole, in our opinion, these projects combining traceable ID through web belong to a category of IoT. The traceable ID of an object plays a role of information shadow [33] and the tracking system through network makes them reappear in the physical world.

There are many products and prototypes of this pattern, such as BookCrossing [5], Cameo & PhotoTag [6], ToyVoyager [37], DiscCrossing [10], Where’s George [41], PostCrossing [27], Geocaching [13], and Wrapsacks [42] etc. see Figure 18.

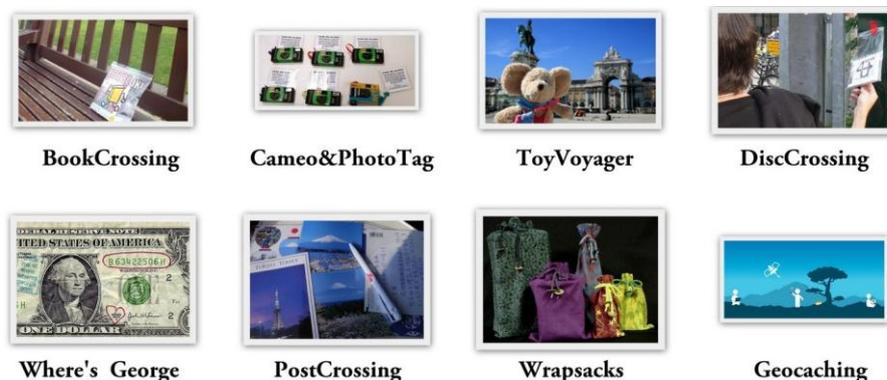


Figure18. Works of IoT belonging to “Something Crossing”

5. Conclusion

From the proposed framework that illustrates four capabilities of a thing and shows the complexity of multiple things separated in the cloud over space and time, we show up a perspective of expression of IoT products in the structure of cloud-based mechanism. Certainly, investigating capabilities of a thing provides a sight to distinguish objects embedded with IoT technology from traditional everyday objects, which helps designers create brand new ideas and better functional experiences by developing products of IoT.

Although the performance of each capability is becoming more functional with the maturity of multiple technologies, designers should be sensitive to perceive new performance of potential function and merge them into design processes rather than focus on technologies themselves.

Furthermore, we demonstrate possible ways of interactive embodiments to help designers unfold expressive ways of interaction in the process of interaction design thinking without being restricted to the hardware and software technologies.

To sum up, we expect that designers are inspired to create better functional products and novel felt experience we live with in terms of aesthetic experiences and expressive interactions by comprehensive analysis of our framework, and to understand potential embodiments regarding time and space under the structure of IoT in this paper.

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