Representing Meaning in User Experience by Visualizing Empirical Data

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Abstract. The study aimed to represent insightful meaning in user experiences by transforming empirical data into visible structural formats in a variety of aspects. To achieve the goal, components of user experience and the process of information visualization from the literature were reviewed. The general process consists of four steps: (1) defining the dimension to construct the data structure, (2) setting the topology to develop the visual structure, (3) giving the relation among the plotted data on the topological map, and (4) integrating the maps to find insightful data patterns by extending and modifying the visual structure. A case study was conducted to demonstrate how the process can be applied. The finding shows how the components and structure have been organized and transformed to provide perceivable information for user experience design.

Keywords: Visualization · Data transformation · User experience · User centered design · Design methodology

1 Introduction

In the current situation of design paradigm shifting from the technology-focused platform to the human-centered platform (Krippendorff 2006), designers are making every effort to understand the problematic situation of users' complex and undefined experiences for better problem-solving. Citing Mitchell's (1993) argument, Redström (2006) explained that design should be focused, not on the problem of a product itself, but on the user experience based on the rich knowledge and deep understanding of the user. Hassenzahl and Tractinsky (2006) devoted their efforts to researching the user experience and emphasized the importance of understanding user experience and applying the insights to the design process.

Wright and McCarthy (2010) asserted that designers should have a holistic approach that human emotion, knowledge, and activity is handled as a comprehensive and inseparable model, instead of a separate analysis of each entity, if they are to view and understand the diverse aspects of user experience in a problematic situation. To have a holistic approach to the user experience, Owen (2007) introduced a few capabilities that designers should adopt, including a perspective focusing on humans and surrounding

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environment, a tendency toward versatility, a subjective use of language, a friendly bond for good teamwork, a combination of potential components instead of making a decision among the imperfect and inflexible answers, and flexibility and communicability through visualization (Razzouk and Shute 2012).

To view the problem in a structured frame, the ability to visualize plays an important role. Visualization can work as an effective medium to transform the abstract concept into a specific and visible element in an orderly layout by organizing and reconstructing massive information identified from the problematic situation.

Information visualization, which has been applied widely in the computer science research field, is a useful methodology to analyze a large amount of information structurally and to interpret the meaning that arises from the information structure succinctly. This method has great potential for designers to adapt a new problem analysis method in the design process. Information architecture is also a general method to organize, systematize, and visually represent massive amounts of data in various research areas. Garrett (2011) explained that this, as a technical method, could help designers view users' experiences in a visible and structural way.

The main goal of the study was to understand meaning in user experience by transforming empirical data into visible structural formats in a variety of aspects.

To achieve the goal of the study, the research is divided into three phases. In the first phase, we looked at comprehensive characteristics of user experience to understand the main components and sub-components of this construct. The second phase explained the process of information visualization. Finally, in the third phase, we applied the process to the in-class design project how to understand meaning in user experience along with visualizing empirical data.

- Phase 1: Understanding of the components and sub-components of user experience
- Phase 2: Review of the process and the principles of information visualization
- Phase 3: Representing meaning with visualization

2 User Experience

2.1 The Components of User Experience

Many researchers have defined the concept of user experience emphasizing the relationship with context. Alben (1996) viewed user experience as a consequence of the interaction between a user and an object that deals with feelings about a product, a user's level of understanding, emotion aroused while using a product, functionality of a product, and accordance with the context of the product-use environment. Goto (2004) and ISO 9241-210 (2010) explained that user experience is the overall user response to a product, system, service, or interaction.

Among the definitions of user experience, the most frequently adapted definition by other researchers is that of Hassenzahl and Tractinsky (2006). They explained that user experience is a series of comprehensive consequences that result from the combination of a user's internal mentality, an attribute of a system, an environment, or context where interactions take place. Based on previous studies, Law et al. (2009) suggested a comprehensive model of user experience that consists of three essential dimensions: person, artifact and context.

From the review of definitions illustrated above, user experience is a consequence of a user's interaction with a product, service, or system. Most researchers agreed that the critical components of user experience include a user and his/her emotion, an artifact's functionality, technology and aesthetics, a diverse context involving time, space, personality of a user, etc. Therefore, as illustrated in Fig. 1, user experience mainly involves a user, artifact, and context, and these components are not independent from each other but rather are interrelated.

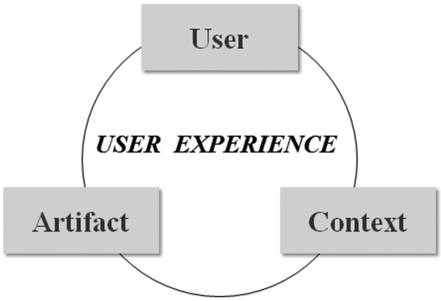

Fig. 1. The three components of user experience: user, artifact, context

According to <User Experience White Paper> (2011), the design elements and assessment criteria in the past have comparatively emphasized the functionality and usability of an artifact, whereas user experience design, at present, focuses on the influence an artifact has on a user and the interpretation of meaning aroused from the interaction between the user and artifact. Supporting this statement, Carlos et al. (2011) explained that successful user experience does not result from the analysis of a big data, but relies on a direct and focused user-centered approach to better identify a problem situation and to better collect problematic information. In summary, the important issue is to collect, analyze, and interpret diverse problematic information in the UX-centered design field.

2.2 The Sub-components of User Experience

The holistic approach in user experience covers from functionality of an artifact to the emotional aspects of a user. <User Experience White Paper> (2011) discussed three components of context, state of a user (motivation, feeling, emotion, expectation, etc.), and system property (from functionality, aesthetics, and response to brand identity) would critically affect user experience, and context could be divided into five sub-categories: social, physical, task, technical, and information context.

Lim and Rogers (2008) divided the design information components into three categories: action, interaction, and object-description. A user's action to an artifact is relevant to an object, location, and time as well as a user and his/her activity. Interaction involves both subject-user and object-user, activity, and time. Object-description refers to information that is relevant to the attributes and functioning of an artifact. They argued that the visualized framework developed based on the above three components could work as a useful lens to organize, save, share, and analyze user experience data.

Goodman et al. (2012) introduced four principles to structure information, people, situations (value, preference, usefulness), activities (level of understanding, satisfaction, a user's skill level), and processes/systems (extra needs, possibility to combine more than two different artifacts).

Carlos et al. (2011) synthesized ideas about the components of user experience and defined the essential components to user experience as following: the user, the artifact (e.g., a product or system), interaction between a user and an artifact, and the context in which a user interacts with an artifact (e.g., particular location and time). They especially emphasized the importance of the context, and categorized it as physical, social, cultural, situational, and temporal.

Table 1. The components of user experience from diverse researchers

UX components	USER	Between user and artifact	Artifact	Context
UX white paper (2011)	User (a person's motivation, mood, current mental and physical resources, and expectations)		System properties (functionality, aesthetics, designed interactive behavior, responsiveness); the properties added or changed in the system, the brand, or the manufacturer's image	Context-social, physical, task, technical, information context-time (before, during, after, long-term)
Carlos et al. (2011)	User	Interaction between user and product	Artifact (product or system)	Context-physical, social, cultural, situational, temporal context
Lim and Rogers (2008)	Action (User, act, object, location, time)	Interaction (Subject-user, act, object-user, tool, time)	Object-description (functionality and attribute)	
Goodman et al. (2012)	People, activity (level of understanding, satisfaction, skill level)		Process or system	Situation-value, preference, usefulness

Based on the various discussions on user experience explained above, the key components of UX can be organized as seen in Table 1. The researchers had slightly different preferences on the terminology, but shared the big picture of the concept that user experience involves a user, an artifact, a context, and an interaction between the user and artifact. The synthesized sub-components for each component of user experience from multiple UX-related authors are classified in Table 2.

Table 2. The UX components & sub-components adapted from UX-related researchers

UX components	USER	Between user & artifact	Artifact	Context
Sub-components	*User's emotion* *User's activity* *User's skill Level*	*Interaction between user and artifact*	*Functionality* *Aesthetics* *Attribute*	*Social context* *Physical context* *Temporal context*-Before/during/after/long-term usage *Situational context*

Table 2 shows that the components of user experience are classified into four viewpoints: User, artifact, context, and interaction between the user and the artifact. The user includes both internal and external aspects, such as emotional response and specific activity as well as the user's skill level to access the artifact. Artifact consists of the functionality, aesthetics, and attributes of a product or a system. Context covers diverse aspects, such as social, physical, temporal, situational, etc.

3 Process of Information Visualization

As we discussed in the previous chapter, user experience is constructed from the interaction between a user and an artifact within a diverse context, which results in some meaning. To fully and deeply understand user experience, it is important to interpret the relationship between the entities and the change that occurs during the experience in a comprehensive and holistic way. Cognitive psychologists Restrepo and Christiaans (2004), viewed user experience as a problem-solving process, thus, design can also be considered as a process to find a solution within a problem space. The problem space is not a physical location; rather, it is more like a metaphorical area where diverse problem-solving activities take place. Restrepo and Christiaans explained that this space includes all the information that could be identified in the process of experience, such as information directly related to the problem, information about the transformation from the problem to a solution, and information related to the potential solution. When we apply this viewpoint to the problematic space in design, user, artifact, context, and interaction can be considered as various types of information that construct the experience.

Therefore, making the UX design information structure more intuitive and insightful requires that designers actively adapt the concept of information visualization, which has been widely used as the information analysis method in various fields since Bertin (1967/1983) and Tufte (1983) introduced the method (Card et al. 1999). Dahl et al. (2001) pointed out that visualization has already been playing an important role in the design process; therefore, it could be a useful method to explore the design problem and its potential solution. They also explained that it is possible to create, interpret, and control information by representing the data in the space through visualization.

Visualizing user experience design information effectively requires understanding the visualization mapping process, which consists of three phases (Card et al. 1999). Card et al. (1999) explained that raw data collected from user research can be transformed into a visual structure that we can recognize through the process of visual mapping by applying spatial attributes, signage, graphical components, etc. The visual mapping process can be summarized as follows: (1) Raw data are organized as a data table through data transformation. The data transform from abstract to structural property, including metadata, by classifying data using variables. (2) The data table is again transformed into a visual structure through visual mapping. The transformed visual structure includes both visibility and topological properties by combining them with spatial substrate, mark, and graphical components. (3) The visual structure is specified and developed into a more recognizable structure by applying graphical parameters through the process of viewing the transformation (Card et al. 1999).

Wurman et al. (Wurman et al. 2000) explained that a process of information visualization consists of three steps: (1) classify data by similarity, (2) arranging data by intention or data meanings, (3) organizing and establishing relations amongst data

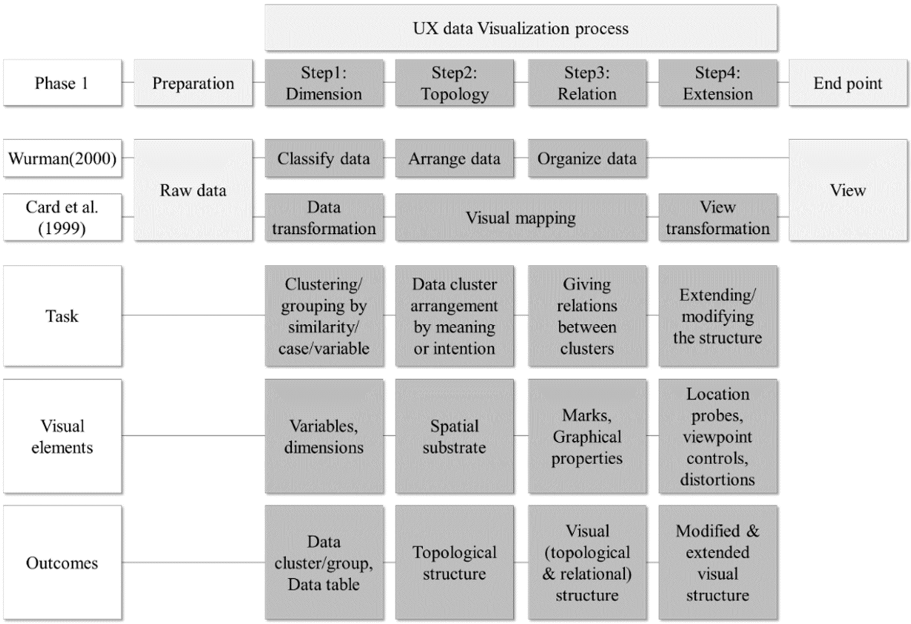

Fig. 2. The process of UX data visualization based on the information visualization process Adapted from the models of Wurman et al. (2000) and Card et al. (1999).

groups or between data entities. By looking at Card et al.'s (1999) model with an overlay of Wurman's processes), visualizing UX data can be inferred as four steps (see Fig. 2) based on the process of information visualization.

The first step in Fig. 2 is a process of transforming UX raw data into a data table. UX raw data can be classified into UX components such as user, artifact, context, and interaction, and their sub-components; these classified UX components are transformed into a data table. In this step, it is important to understand an attribute of data, and then transform that attribute into a proper variable by project or research goals because the variables work as dimensions to transform the data table into a topological structure.

The second step is to transform the data table into a topological structure by applying a spatial substrate. To better interpret UX data, the key principle of this step is to make full use of the visual mapping process that transforms a data table consisting of invisible and non-topological data entities or data clusters into a visual structure that has a visible attribute based on topology. Spatial substrate is an essential element to construct a visual structure, and it plays a key role in transforming non-topological data attributes into a location-based attributes.

The third step is to transform a topology-applied data structure into a more visible structure. In this step, the relations amongst data can be revealed more clearly by organizing the data using marks and graphical properties. Marks create relations and flow amongst location-based attributes to deal with the four types of point, line, area, and volume. Graphical properties help the data of which location and relation are pre-defined to be presented in more structured way using position, gray scale, orientation, color, texture, shape, etc.

The fourth step is to modify the visual structure to add a dynamic visibility using graphical variables such as location probes, viewpoint controls, and distortions. This step enables people to better perceive visual structures by bringing a dynamic interaction between human and data (Card et al. 1999).

4 Case Study: Anti-crime Project at University Area

The case study was used an anti-crime design project for university students living apart from their families, and renting rooms around the university. The goal of this UX design project was to provide students with safety when commuting to and from school. Team members conducted user research on student lifestyles regarding commuting patterns, and followed the design process based on the visualization framework to analyze the UX data. The result led to two meaningful insights drawn from the analysis: (1) a safe zone as a place of refuge in case of an emergency, (2) an easy and quick way-finding system in a winding and narrow alley. The following case study is used to explain the process of applying the visualization framework to the anti-crime design project to assess its practical use and offer a rationale for each step.

Firstly, in the <Dimension> step, the data collected from the UX research on anti-crime for university students was classified into the three UX components: user, artifact, and context. To define sub-components, the dimensions were defined as shown in Table 3 considering the attribute of data and project goal. For the user component, data were classified into the three user types: a student living apart from his/her own family who was the main target of the project, a police officer who was in direct charge of local anti-crime, and an employee working at a store/café/shop during the day and night who had a potential influence on students by frequently interacting with them in business. For the artifact component, all environmental elements that had the possibility to either induce or prevent a crime were included, as were public facilities provided for local anti-crime efforts. As latent elements for safety, business stores and landmarks in the area were also included to the artifact. For the context component, the data were classified into day/night by temporal aspects and main street/alley by the aspect of physical context with consideration for the fact that the crime rate could be highly affected by timeline and locational character.

Table 3. The UX components & sub-components by dimensions regarding safe return home

<table>
<tr><th>UX components</th><th>Dimension</th><th colspan="2">Sub-component</th></tr>
<tr><td rowspan="3">User</td><td>Main target</td><td>Student</td><td rowspan="3">-usual path
-daily lifestyle & commuting pattern
-emotional state & experience on crime</td></tr>
<tr><td>Direct influence</td><td>Police officer</td></tr>
<tr><td>Indirect influence</td><td>Employee at business store</td></tr>
<tr><td rowspan="3">Artifact</td><td>Safe</td><td colspan="2">Public facility (street light, CCTV)</td></tr>
<tr><td>Non-safe</td><td colspan="2">Blind spot, broken/unattended facility</td></tr>
<tr><td>Latent/neutral</td><td colspan="2">Business store, landmark</td></tr>
<tr><td rowspan="2">Context</td><td>Temporal</td><td colspan="2">Day/night</td></tr>
<tr><td>physical</td><td colspan="2">Main street/alley</td></tr>
</table>

To reach the goal of a safe return home, one must understand the contextual meaning of safety regarding the collected data. In the second step, to interpret the classified data shown in Table 3 from the aspect of safety, two topological spaces were formulated: the geographic map and the Venn diagram. Firstly, as illustrated in Fig. 3, the geographic map was chosen because of the common geographical position of users' paths and the

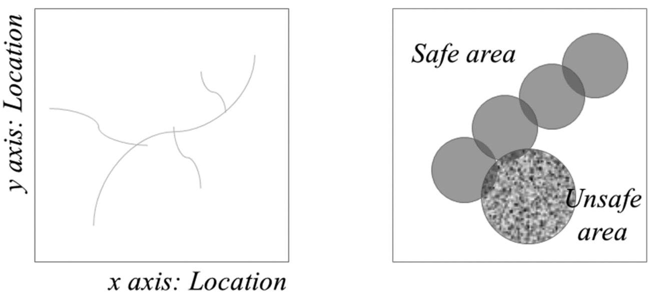

Fig. 3. The two different types of topological map formulated for anti-crime design project: geographic map (left) & Venn diagram (right)

sub-components of the artifact (facility, landmark, stores, etc.), and because the meanings of data could be easily identified by the dimensions of safe/non-safe/potential viewpoints based on the geographical distribution of data on the map.

On the map, the users' paths and locations of artifacts could be visually identified, and temporal/physical contexts at a particular area could be represented using the x and y axes to indicate geographical positions. Secondly, the Venn diagram was used to distinguish relative areas according to the frequency of crime and the degree of anxiety considering that crime rate and users' emotional states could be affected by temporal and locational characters. In this case study, judging from the brightness of light by day and night, the openness and crowdedness of areas, and students' anxiety about crime, the Venn diagram consisted of two different categories: safe versus unsafe areas.

In the third step, the team members actually plotted the UX data on the topological maps formulated in the previous step, and gave visible relations between the data entities. To identify the pattern of data distribution clearly regarding safe/unsafe aspects, the visual structure (see Fig. 4) was developed by overlaying the network map onto the plotted data on the topological map.

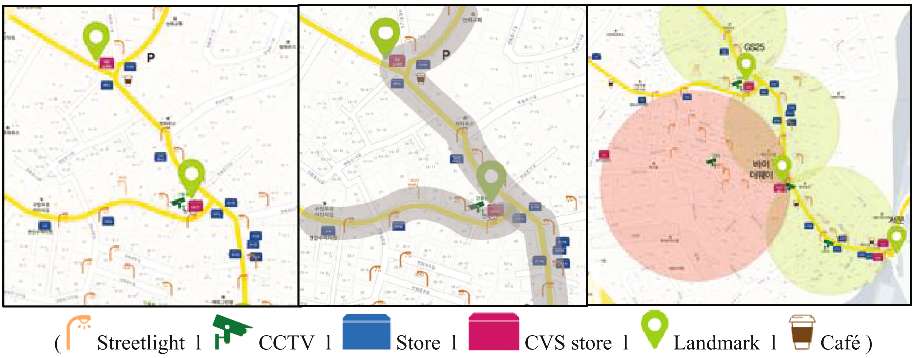

Fig. 4. The visual structures developed with the application of topology and relation: the geographic map (left), the network map (middle), and the Venn diagram (right)

The left and center images in Fig. 4 were partial results of the developed visual structure. The left image shows the location of street lights belonging to the safe element on the geographic map, while the center image represents the overlay of the network map onto the geographic map using a thick translucent line following the regular distribution of streetlights. The left image in Fig. 4 also visually represents the locations of stores, landmarks, and CCTV using different icons for each artifact; locations of streetlights are also included. Comparing the left and center images, the topological map (left image) itself does not reveal a meaningful pattern because the plotted data entities were meaninglessly scattered on the map. However, the visual relation given among the data entities, which shared the same attributes, could suddenly reveal a meaningful visible pattern. For example, the network map overlaid onto the topological map in Fig. 4 (middle image) could be interpreted that the regular distribution and high frequency of streetlights work as positive elements for students' safe returns home and correspond mainly to the main streets.

Meanwhile, the right image in Fig. 4 was the result of the Venn diagram distinguishing between the safe and unsafe areas according to crime rate and users' emotional states, which could be affected by the timeline (day and night) and locational characters (openness, crowdedness, etc.). For better distinction between the areas, safe areas with low crime rates and less anxiety is colored in green, while the unsafe areas with relatively high crime rates and more anxiety for crime are colored in red. In summary, by plotting the UX data and visualizing the relation between the data on topological maps, the meanings of data clusters formulated by the dimensions and attributes applied to classify the UX data and the independent meanings of each data entity could be interpreted more clearly.

In the fourth step of <Integration>, to draw meaningful insights from the data patterns for the safe return home, the geographic map with relations and the Venn diagram were integrated into a map using the medium of shared attributes between the visual structures. The geographic map was developed based on the locational attribute of artifacts, and the Venn diagram was formulated using the dimension of safe/unsafe area. Accordingly, the two topological maps turned out to share the attribute of space. The Fig. 5 resulted from the integration of the two maps centering on the geographic map that holistically reflected the space attribute of geographical position and distinguished area.

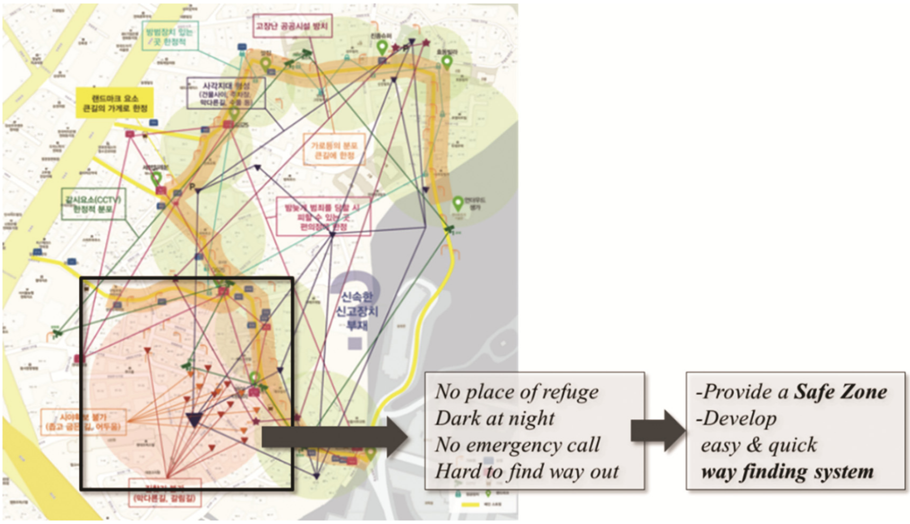

Fig. 5. The integrated analysis map developed through the visualization framework

For example, as shown in Fig. 5, insights were drawn from the integration of the network map for streetlights and convenience stores and the Venn diagram as follows. The streetlights located on the allies were irregularly and rarely distributed unlike those on the main street, which aroused students' anxiety because of blind spots and darkness.

The interesting fact resulting from the integration of the maps was that the convenience stores and the employees could be potential safe places and guards for crime because of their around-the-clock business hours. Referring to this fact, the safe areas (a convenience store, a police station, including the anti-crime checkpoint) for commuting were specifically identified. Accordingly, it was discussed that the design possibility of how a police officer, an employee at a convenience store, and a pedestrian could cooperate in case of an urgent crime in the area. As a result of the discussion, the two key insights drawn were as follows. (1) The safe zone could function as a shelter in case of emergency. In addition, the UX design concepts were discussed on how to transform the blind spots as potentially threatening elements for safety in the safe areas, and how to provide immediate and better access to these potential safe guards and/or places. (2) The easy and quick way-finding system in the potentially unsafe zone, such as narrow and winding allies, was suggested from the visualized analysis. Figure 5 illustrates the final integrated analysis map for the anti-crime project developed through the visualization framework of the four steps in which the plotted UX data regarding anti-crime on the geographic map and the Venn diagram was integrated into a map in relation to the data.

From a review of the first case study, it was found that the meaningful information could be drawn from the data using the visualization framework. It was also revealed that the information could be transformed into the principles for design concept development using integrative interpretation.

The rationale used for the visualization framework in this case study is illustrated in Fig. 6. Firstly, to reach the project goal of safe return home and define the safe zone for university students, the UX data collected from the research were classified into categories by adding dimensions considering the goal. Secondly, both a geographic map capable of representing location of data and a Venn diagram to conceptualize the safe attributes were defined as topology for the primary visualization of UX data. Thirdly, the classified data were plotted onto the map, followed by setting the network relations among the data to reveal the visible data patterns. Finally, the topological maps with relations were integrated into a map centered on the attributes of safety, which led to

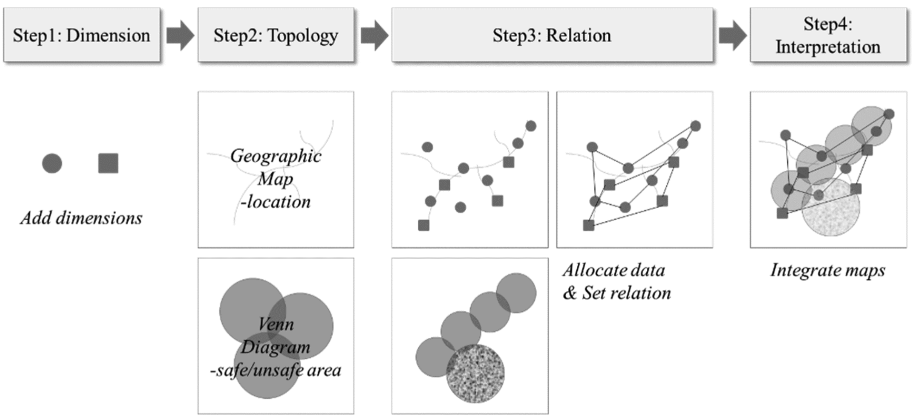

Fig. 6. The rationale used for each step of the visualization framework in case study 1

the integrative interpretation of UX data patterns regarding a safe return home as the project goal.

5 Conclusion

To better interpret the insightful meanings of UX data, this study attempted to establish four-steps-visualization-process. The first step, <Dimension>, constructs the data structure by classifying the UX components into the user, artifact, context, and interaction, with consideration for a project goal. The second step, <Topology>, sets the basic structure of the topological space according to the meaningful attributes of UX components to intuitively interpret the data. The third step, <Relation>, develops the visual structure by giving process or network relations to the topological space with the UX data plotted onto that space. The fourth step, <Integration>, involves the comprehensive interpretation of insightful meanings according to the project goal based on the complex relationships among the data patterns identified from each visual structures as well as the integration of multiple visual structures developed with topology and relation applied in the previous step.

From the above case study, this paper concludes that the four-steps-visualization-process shows the possibility of being applied to a design project in the form of a flexible visual structure with various combinations of topology and relation according to a design goal. It can also be concluded that the process is useful to structurally interpret meaningful insights by visualizing the UX data patterns within the process of each step. Further research should be done to develop a general framework and design toolkit for the visualization process by conducting a variety of case studies and iterating the refinement of the process. It is also expected that various types of methods for interpreting UX data meaning be suggested with examples using a combination of topology and relation according to the UX project goals and subjects.

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