Development of Web based UX Diagnosis System
for Small and Medium Sized Home Appliance Manufacturers in the IoT Era

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Abstract — **The purpose of the study is to develop a web based User eXperience (UX) diagnosis system that helps the small and medium sized home appliance manufacturers prepare for the opportunities of Internet of Things (IoT) era. To provide a UX diagnostic system that is compatible with various product types of the home appliance manufacturers, a total 109 questionnaire items for UX evaluation were developed based on the UX design principles and design elements. The functional requirements of the proposed diagnosis system were constructed based on the needs and requirements that collected from the designers of the small and medium sized manufacturers though in-depth interviews. A UX diagnostic system was developed as a web based platform that supporting overall UX diagnosis process, from the questionnaire generation, survey distribution, user survey data collection, and visualization of the analyzed UX diagnosis result. The proposed system is designed to uncover various possible UX design flaws related to specific design elements and UX design principle. The proposed system provides both quantitative and qualitative diagnosis results, such as UX design scores and users' comments and opinions about the products. The usability, validity, and usefulness of the developed system were evaluated by the experts through case study. The developed system is expected to be useful for home appliance designers of the home appliance manufacturers by providing systems to evaluate the current state of their products and uncover the UX design issues through a web based survey. The following study will be focused to provide design elements, UX design principles, and questionnaire items for evaluation of the home appliances' IoT features.**

Keywords- User experience; IoT; Home appliance; UX diagnosis system; Survey system

I. INTRODUCTION

UX (User eXperience) became very popular and important concept to be considered by product designers to achieve competitive advantage in the market. The User Experience can be defined as a person's overarching experience that consists of all aspects of users' interaction with a product, system or service [1]-[3]. The detailed aspects that influence the UX satisfaction of the users may can be varied by the application domains and academic fields, however, usability [3]-[5], affect [3], and user value [3], [6]-[12] of the products are considered to be the most important criteria for UX evaluation by many researchers.

Nowadays, designers of the home appliance manufacturers also started to consider the UX of their product to enhance the user satisfaction. Home appliance is a set of electronic devices that assisting household jobs. Home appliance manufacturers who have enough resources are trying to enhance the UX of their products by investing their resources to introduce state-of-art UX design techniques. However, the Small and Medium sized Enterprise (SME) manufacturers that taking a large portion of the Korean home appliance market usually does not have enough resources and tools for product UX enhancements. As the Internet of Things (IoT) technologies are leading trend of the home appliance market, gradually SME manufacturers are forced to develop new home appliances that have various new IoT features. As a result, it is needed to propose a UX diagnosis system that can reduce the risk of the failures that caused by design by supporting the development process of the SME manufacturers. The diagnosis system has to be afforded to SME manufactures and compatible to their various home appliance product spectrum. The purpose of this research is to develop a UX diagnosis system for designers of the SME home appliance manufacturers based on the requirements and needs that reported by the designers. This study is research that covers the UX diagnosis of traditional home appliance types before the extended research on the UX evaluation of the IoT features of home appliance.

In Section 2, research target home appliance products were defined and the requirement of the designers were explored and analyzed. In Section 3, the proposed diagnosis system was designed and developed. In Section 4, the architecture and interfaces of developed system were described. In Section 5, the case study was proceeded to validate the system's usability. In Section 6 and 7, the discussion and conclusion were followed.

II. REQUIREMENT ANALYSIS ON HOME APPLIANCE PRODUCTS DESIGNERS

Currently, a lot of types of the home appliances are distributed on the market. The types of the home appliance product are varied as the number of the household jobs. This research covers the 6 categories and 27 sub-categories of the home appliance types (See, table 1).

TABLE I. TARGET HOME APPLIANCES OF THE RESEARCH

Category	Home Appliance
Cleaner	Vacuum cleaner, Robot vacuum, Handheld vacuum
Kitchen	Rice cooker, Electric kettles, Blender, Water filter/purifier, Electric range, Microwave oven, Electronic oven, Toaster, Dishwasher
Laundry	Iron, Washing machine
Beauty	Hair dryer, Hair straighteners, Electric shaver
Heater/Air Conditioner	Fan, Dehumidifier, Humidifier, Air purifier, Heater, Fan heater
Health Care	Hearing aid, Massager, Handheld massager

The requirements of the UX diagnosis system were needed to be defined based on the demands of the designers. In-depth interview sessions were placed to collect the opinions and demands of the designers on the UX evaluation and diagnostic tools they have experienced. A total nine SME designers who take the role of operating designers, engineers, and Chief Executive Officers (CEO) of six SME home appliance manufacturers were participated in the interview. Designers shared their needs, pain-points, and episodes that they experienced during UX diagnosis or product design enhancement process. They also provided valuable opinions about the ideal concept and the role of the UX diagnosis system based on their experiences (See, table 2). These opinions were translated into the system design requirements to reflect the designers' demands of researchers

III. UX DIAGNOSIS SYSTEM DESIGN

The system was designed through following three steps. At first, the UX design principles and design elements were defined. And questionnaire items for UX evaluation were generated by combining the principles and design elements. At last, the web based diagnosis system was developed.

A. *UX design Principles and Design Elements*

To define major criteria for evaluating UX satisfaction of the home appliance products, the UX related principles and evaluation criteria were collected through home appliance

designer interview and literature review. The collected UX design principles were merged into 14 UX design principles and categorized into three UX aspects such as usability, affect, and user value (See, table 3).

TABLE II. SME DESIGNERS DEMANDS ON UX DIAGNOSIS SYSTEM

Category	Demands
Accessibility	▪ The system has to be easily accessible by external participants ▪ Survey session needs to be around 15 minutes to reduce cognitive workload ▪ Survey process and questionnaires have to be easy and simple
Usability	▪ Easy for participants to rate products ▪ Easy for designers to use the system ▪ Easy/clear terminologies need to be used
User Characteristics	▪ Demographic information of the user has to be analyzed ▪ The answering tendency of the participants' demographic characteristics towards each UX element is very important information for market segmentation and strategy
Customizability	▪ Designers may need to select, add, modify, remove questionnaire items ▪ System need to provide customizability for designers
Comments Analysis	▪ User comments are also a very important source of the ideas, issues, opinions ▪ It is needed to provide functions to collect and analyze user's comments
Comparison	▪ Comparison between products are very important to provide understanding about current market's UX levels and criteria for judgement
Price Decision	▪ The system may can provide the criteria for the pricing decision
Pros/Cons Analysis	▪ System need to provide information about current weak point and the strength of the product

TABLE III. UX DESIGN PRINCIPLES FOR HOME APPLIANCES

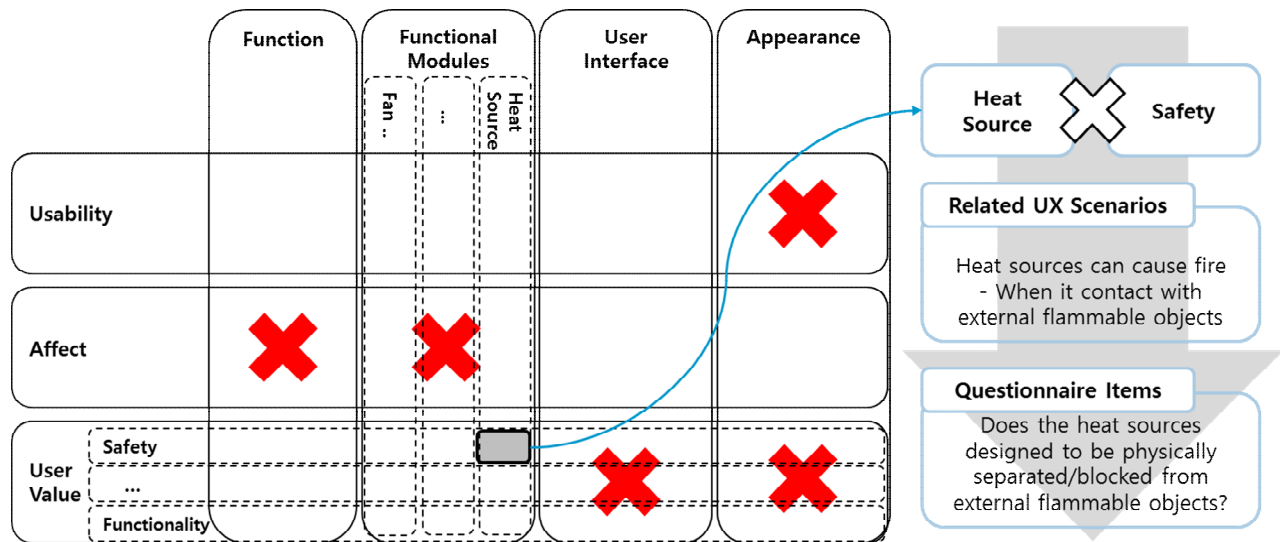| UX Aspect	UX Design Principle
Usability	▪ Informativeness ▪ Learnability ▪ Efficiency ▪ Physical suitability
Affect	▪ Attractiveness ▪ Delicacy ▪ Luxuriousness ▪ Stability ▪ Harmoniousness
User Value	▪ Safety ▪ Hygiene ▪ Durability ▪ Performance ▪ Functionality

Figure 1. Development Process of Questionnaire Items

It is also important to investigate the source of the poor UX for design enhancement. Design elements of the home appliance were defined as the logical and physical components of products that can be designed by designers and influence the UX satisfaction of the users such as function, interface, and appearance of the product. The design elements of various home appliances that could affect to the UX satisfaction were collected from literatures, user reviews, and expert interviews.

TABLE IV.   DESIGN ELEMENTS OF HOME APPLIANCES

Category	Design Element
Function	▪ Function
Functional Module	▪ Ventilation Opening ▪ Filter/Dust Bag ▪ Fan/Motor ▪ Heat Source ▪ Sensor ▪ Handle/Grip ▪ Wheel ▪ Feet ▪ Cover/Lid ▪ Replaceable Module ▪ Power Supply Cable ▪ Battery ▪ Bottle/Vessel
User Interface	▪ Visual Information/Display ▪ Sound/Speaker ▪ Haptic Stimulus ▪ Control
Appearance	▪ Color/Painting ▪ Texture ▪ Shape

A total number of 21 design elements were defined and classified into four categories, such as the function,

functional module, appearance, and user interface elements (See, table 4).

B. Development of UX Evaluation Questionnaire Items

It is important to develop detailed questionnaire items that could be related to various home appliance design flaws. The proposed system uses UX design principles as evaluation criteria and design elements as the targets to be evaluated. The questionnaire items were developed based on the combinations of these two factors. As fourteen UX design principles and twenty-one design elements were defined, a total of 294 combinations were available.

To develop the questionnaire items based on the possible use scenarios related to design flaws, scenarios that could be happened during context of use were constructed and reviewed for each combination. Questionnaire items were developed based on the scenarios to ask users if the target product is appropriately designed to prevent the related UX problems. For example, combining a heat source with the safety principle, safety related problematic scenarios could be deduced and following questionnaire items were developed based on these scenarios (See, Figure 1).

As a result, a total 109 questionnaire items were defined based the UX related principles and design elements of the home appliance types. Each questionnaire item was designed to be related to the specific UX design principle and the specific design element.

C. UX Diagnosis System Development

The UX diagnosis system was developed as a web-based responsive survey system that running on Apache Tomcat. The system was designed to be web-based survey system. The system design followed the requirements that collected from the designers of SME designers by providing related functions to evaluate the home appliance and inspect possible design flaws.
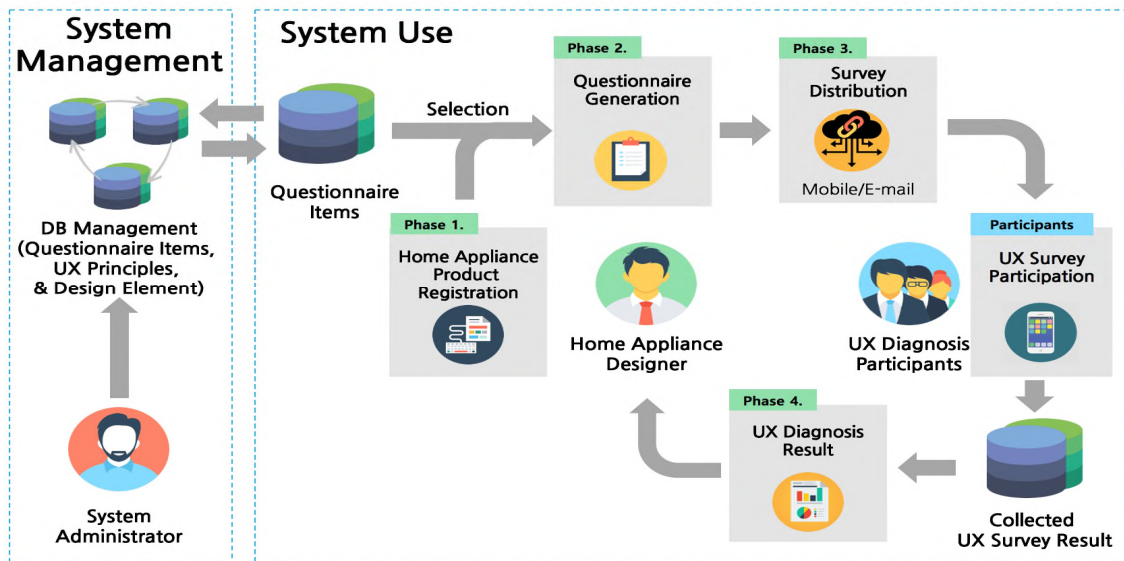
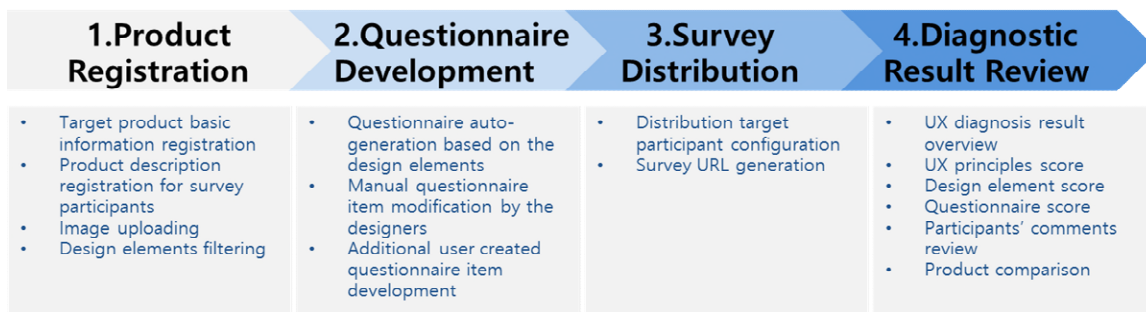Figure 2.   UX Diagnosis System Architecture

Figure 3.   UX Diagnosis Process and Designers Tasks

IV.   RESULT: UX DIAGNOSIS SYSTEM

On the proposed UX diagnosis system, home appliance designers can follow four steps to generate, distribute, and read the result of the UX diagnosis survey (See, Fig. 2). The developed system provides questionnaire items and related functions to support home appliance designers through the UX diagnosis process (See, Fig. 3).

The first stage is the product registration phase. SME designers can register the information about the product to be evaluated. The information about the product such as major functions and images were designed be presented to survey participants as supplemental information to provide better understanding about questionnaire item.

The second stage is questionnaire development phase. The system generates questionnaire automatically based on the design elements consisting the target product. The designers can modify any questionnaire items to specify the terminologies to fit on the product components, and also remove any questionnaire items if they were considered not to be important (See, Figure 4). The designers can also add any questionnaire items to collect additional user opinions.

The third stage is survey distribution. The UX diagnosis system generates a Uniform Resource Locator (URL) of the survey that can be distributed through email or message. The survey participants can access to the survey on any devices through internet connection by clicking the survey URL.

Figure 4.   Questionnaire Item Modification Interface

During the survey, each questionnaire item was presented to participants with supplementary information such as images and related design element description. The participants were instructed to rate with 0 to 100 scale for

each questionnaire item (See, Figure 5). The participants can provide any comment or opinion to describe why they rate so through the survey process.
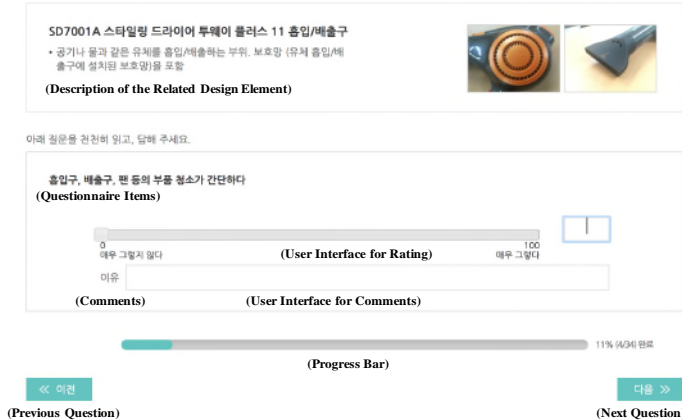

Figure 5.   Survey Questionnaire Interface for Participants (Translated)

The last stage is the diagnostic result review. The web diagnosis system generates the diagnostic report for SME designers based on the survey participants' responses. Designers can review which UX design principle or design element were evaluated high or low by participants with the proposed system. The diagnostic result contains visualized information about the response of each demographic group. The designers also can review the critical design issues and related opinions on the diagnostic report to get a hint for the further design enhancements.

The system provides several distinct interfaces to visualize the products' scores and participants' responses. For examples, the product comparison function generates reports to visualize the UX diagnosis results of products through side-by-side view (See, Figure 6). This interface uses a bar - chart to visualize the scores of each product to be easily compared by the designers.
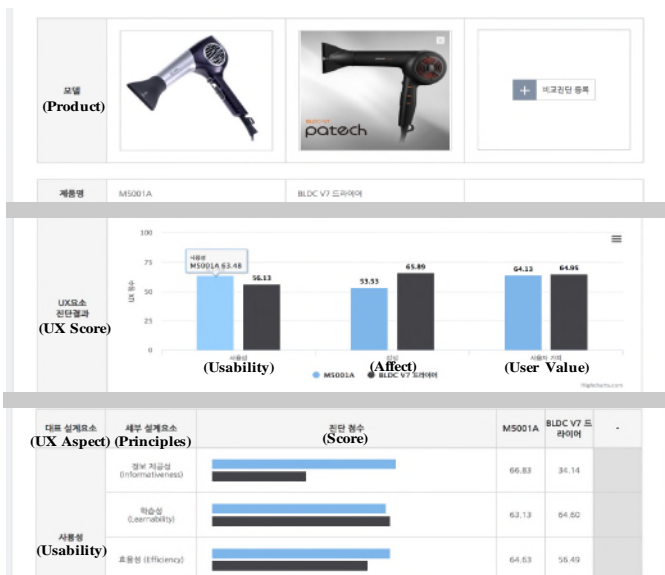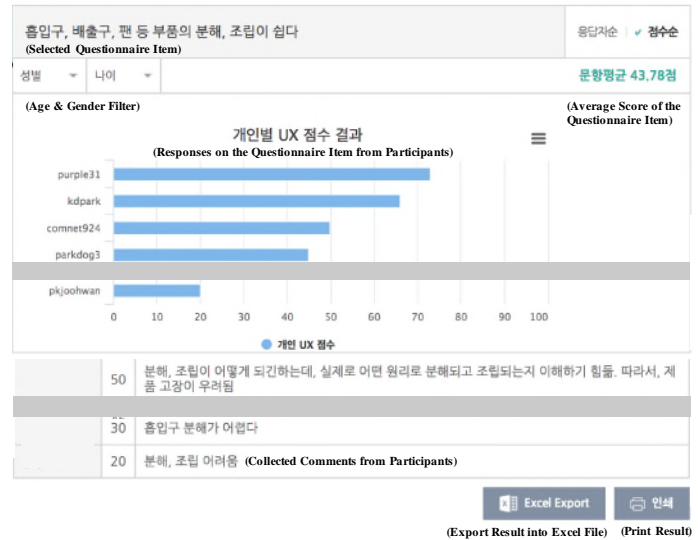

Figure 6.   Result: Product Comparison

Figure 7.   Result: Participants' Responses on Specific Questionnaire Item

The system also provides the interface to show the participants' responses to each questionnaire item, such as rating score, gender, age, and comments (See, Figure 7).

V.   CASE STUDY: SYSTEM USABILITY EVALUATION

To validate the usability of the proposed system for the realistic home appliance UX diagnosis purpose, the usability of the proposed system was evaluated by expert group consists of UX experts and SME designers. The UX expert group consisted of six UX experts who have a Doctor of Philosophy (Ph.D.) degree of UX related domains and nine industrial designers of the SME manufacturers.

TABLE V.   AVERAGE USABILITY EVALUATION RESULT

SUS Questionnaire Item	UX Expert	SME Designer
I think that I would like to use this system frequently.	91.3	77.2
I found the system unnecessarily complex.	88.9	80.0
I thought the system was easy to use.	85.1	83.9
I think that I would need the support of a technical person to be able to use this system.	81.9	73.9
I found the various functions in this system were well integrated.	88.1	76.7
I thought there was too much inconsistency in this system.	82.8	82.2
I would imagine that most people would learn to use this system very quickly.	84.7	85.6
I found the system very cumbersome to use.	82.3	81.7
I felt very confident using the system.	87.2	87.8
I needed to learn a lot of things before I could get going with this system.	81.7	82.8
Mean score	**85.4**	**81.2**

System Usability Scale (SUS) is usually used as a system usability evaluation questionnaire [13]. SUS is one of the most qualified and simple usability evaluation tools that uses ten questionnaire items for software usability evaluation. To verify the usability of the proposed system, experts reviewed

the proposed system and evaluated the usability of the system. UX diagnosis results of nine home appliance products were collected from ten users and presented to experts as examples. The overall average SUS score was over 80 points on the both groups (See, table 5).

VI. DISCUSSION

Several survey participants reported that it is hard to perform objective evaluations on specific product design because of the lack of the expertise. As the psychophysical scale methods are used to quantify the users' subjective judgement to measurable index, when users do not have enough experience it can be hard to quantify the subjective judgement on the product [14]-[16].

There was a concern that reported by SME designers about the bias caused by participant variability. Reliability of the rating score may differ because the relative indicators may change depending on the user's evaluation criteria. Some researcher pointed out the possible bias that based on the inter- and intra- subject variabilities [17]-[20]. The number of participants must be compensated at least ten and more participants are required to overcome the inter- and intra-subject variability when using the magnitude estimation technique [20].

As the home appliance industry is currently following the trend of the IoT, the proposed diagnosis system needs to be enhanced to compatible with the IoT home appliance products. The deduced UX design principles and design elements are developed based on the popular and representative products on the market, not based on state-of-art IoT products. It means they are currently not sufficiently comprehensive to cover the various IoT based functions and IoT related functional modules that consisting IoT home appliance products. The future research is currently planning to expand provided system to support IoT home appliance products.

The purpose of this research is to develop a UX diagnosis system for designers of the SME home appliance manufacturers based on the requirements and needs that reported by the designers. This study covers the UX diagnosis of basic home appliance types, and the extended research on the UX evaluation of the IoT features of home appliance will be followed.

VII. CONCLUSION

The developed system is designed based on the demands of the designers of the SME home appliance manufacturers. The developed system provides the systematic UX diagnosis system that is compatible and flexible to various home appliance types. The inspection and diagnosis result of the proposed system could be helpful for SME manufacturers to find design flaws of their product and hints for further design improvement.

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