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博 士 論 文 概 要

論 文 題 目

Exploring Gamification Design and Virtual Marker Technique Under the AR Framework

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Mobile e-commerce (M-commerce) is one of electronic commerce that uses mobile devices such as smartphones and tablets. M-commerce consists of mobile shopping and mobile payment. The point system is one of the loyalty programs for rewarding customers after payment in mobile payment. Combining the characteristics of mobile devices to design next-generation point systems could bring new benefits to M-commerce. On the other hand, augmented reality (AR) applications are becoming more and more important on mobile devices. Mobile devices that can support AR are being put to practical use at a very fast speed. The purpose of this dissertation is to design a next-generation point system based on AR and mobile devices, and to propose techniques for developing AR applications that can be easily operated on mobile devices. To achieve this goal, I have proposed a gamified point system based on AR and mobile devices, and quantitatively evaluated its effects in Chapters 2 and 3. In Chapter 4, the concept of "virtual markers" that exist only in the AR world is proposed, in addition to the conventional physical AR markers. The concept is given from the viewpoint of developing AR applications that can be easily operated on mobile devices. It is implemented and tested through a pilot study. I have also illustrated how to use virtual markers to implement a framework for a gamified point system based on AR and mobile devices.

Chapter 1 explains the prerequisite knowledge of this research, "AR", "gamification", and "mobile e-commerce". With the spread of mobile devices, it has become possible to realize the point system on mobile devices. Compared to traditional loyalty card and stamp card loyalty systems, loyalty systems on mobile devices can update points more quickly, providing users with a dynamic and engaging interactive display.

In Chapter 2, AR-based 3D character design has been proposed as a way to visualize the "competition" of shopping behavior for the point system, and has been compared with traditional text-based design and 2D image design. The competition-based loyalty system provides dynamic feedback for the user's shopping through the user's competitive awareness. In addition, the traditional point system is to reward users for shopping. In this research, the mission is introduced. Users can make purchases to achieve the goal of "environmental protection", "health" and "localization". I have introduced gamification mechanisms to realize new values beyond economic motivations, such as social values. Users can complete missions according to their preferences. I have conducted an evaluation experiment and confirmed that participants who used AR-based 3D character designs completed more missions than 2D and text-based designs. Compared with 2D-based ($p < 0.001$) and text-based ($p < 0.001$) design,

the pairwise comparisons using the Bonferroni method revealed that AR-based 3D character design significantly increases users' willingness to spend more time in the competitive experience.

In Chapter 3, the marker-based AR point system described in Chapter 2 has been further expanded, and the effects of each element of gamification and the effects of social interactions such as "competition" and "cooperation" have been evaluated. As an extension of the AR point system, I have prepared a virtual pet as a 3D character and provide value points as rewards for completing missions. Users get value points after completing missions. The user can use the value points to purchase virtual food to restore the energy of the virtual pet. Based on these game elements, users can conduct social interactions such as "competition" and "cooperation" with other users. Users can "compete" with each other through their virtual pets, or "cooperate" with each other by distributing virtual food to other users' virtual pets. The first evaluation experiment examined the impact of missions and pet-based feedback on purchase motivation. Pairwise comparisons using Bonferroni's method show that pet-based feedback motivates users to purchase ($p = 0.001$), and missions affect users' purchase choices ($p < 0.005$). In the second evaluation experiment, a single-user system was compared with a multi-user system. The results showed that in a multi-user system with social interaction, the system usage has increased significantly.

In Chapter 4, I have proposed the concept of "virtual markers" that only exist in the AR world. The concept was implemented and tested from the perspective of developing AR applications that are easy to operate on mobile devices. The virtual marker is generated from a physical template marker or from an existing virtual marker. Users can customize and use virtual markers. Multiple AR markers, including virtual and physical markers, can work together. The virtual marker technique can be used to manipulate AR objects more conveniently and improve the interactivity and scalability of the marker-based AR system. The arrangement of multiple AR markers can be divided into two categories. One is to arrange and link multiple AR markers in one or two dimensions, and the other is to dynamically arrange multiple disordered AR markers through gestures. I have designed a series of gestures to manipulate virtual markers. The user can create a program by arranging multiple AR markers in a specific order or dynamically link multiple AR markers through gestures. The result is displayed on the AR marker and can be confirmed by the superimposed information on the AR marker. I have conducted a pilot study in which experimenters created a simple program with multiple AR markers to verify the effectiveness of virtual markers. The pilot study showed that the

experimenters quickly adapted to gesture operations and smoothly controlled virtual markers. I have also provided a framework to illustrate how to use virtual markers to implement a gamified point system based on AR and mobile devices. First, a virtual point card is created using the virtual marker technique for the conventional physical point card that displays AR content. In addition, the operations of virtual pets, value points, and virtual foods on the point card are controlled by function markers and action markers, which are programs created by multiple AR markers. It was shown that by using this framework, social interactions such as "competition" and "cooperation" of multiple users can be realized in the point system implemented on mobile devices.

Chapter 5 concluded this dissertation and described our future work. The future e-commerce environment will no longer be limited to traditional web browsing mode and mouse-keyboard interaction. 3D avatars and new interactive techniques can be potentially valuable to promote the development of e-commerce. In addition, social elements can be introduced into the new shopping environment to provide a more engaging shopping experience. Our research introduced social elements and 3D avatars into the point system to build a gamified AR framework. The virtual marker technique was proposed to expand the interactivity and scalability of the AR framework. Future issues include customization of 3D avatars, diversification of missions, long-term operation evaluation of the proposed point system, and further enhancement of virtual markers.