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研究課題名（和文）Study and development of smart supermarket by using visible light communication (VLC) and smartphone technologies

研究課題名（英文）Study and development of smart supermarket by using visible light communication (VLC) and smartphone technologies

研究代表者

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研究成果の概要（和文）：本プロジェクトの主な成果は2つある。一つ目はシステムのデザインと概念実証の実装。それは：VLCに基づいた測位システム、新たに開発された位置識別交換プロトコルを用いたスマートカートに搭載されたスマートフォン・タブレットのためのプロトタイプ受信機、クラウドに基づいたデータ分析の枠組みに関する勧告である。二つ目はマルチユーザVLCネットワーク及びビデオストリーミングを含む実現技術の検討。特にユーザのサービス品質や経験品質やVLCのセキュリティなどを向上させる技術に焦点を当てる。さらに、VLCに基づいた室内測位システムの精度とスケーラビリティを向上させるための新しい超音波測位方式を開発している。

研究成果の概要（英文）：The project has two main achievements. First, it is the design and implementation of the proof of concept of the system that includes (1) VLC-based positioning system, (2) a prototype receiver for smartphone/table mounted on smart cart using a newly developed location identification (ID) exchange protocol to communicate with VLC beacon, and (3) recommendation on framework of cloud-based sale data analysis based on R supporting user shopping experience. Secondly, we study the feasibility of enabling technologies supporting the framework of smart supermarket environment, including broadband multi-user VLC data network, video streaming over Hypertext Transfer Protocol (HTTP/2) with a special attention to technique to improve the user quality of service and quality of experience, security issues of VLC networks in the context of multiple users. In addition, we also develop a new ultra-sound positing method to improve the accuracy and scalability of VLC-based indoor positioning system.

研究分野：　情報学

キーワード：　VLC　Untra-sound　Indoor Localization　Video Streaming　HTTP/2　Internet of Things　Network Security　RFID

１．研究開始当初の背景

The future of public lighting is currently moving in the direction of being multifunctional, modern light sources have the capacity for illumination and concurrent wireless data transmission. The merger of these two applications has been made possible through solid-state high brightness light emitting diode (LED) technology. Recently, LEDs have consistently increased the light generated per package by a factor of twenty, whereas the cost per lumen has fallen by a factor of ten, every ten years accordingly the Haitz's law.

Figure 1: Illustration of SMARTKet concept.

Short-range optical wireless communication utilizing the visible spectrum emitted from the LEDs, referred to as visible light communication (VLC), transmits data via modulation of the light intensity [1]. So far, the VLC capability is above 1 Gbit/s with a reasonable coverage range that is applicable for home/office environment [2]. VLC also offers a complementary scheme to radio-frequency (RF) communications; using a license free spectrum and inherently secure connections (as light cannot propagate through the surrounding walls) as well as offering immunity to all RF interference. The dual functionality required from the LED creates the unique opportunity for indoor localization which is much more precise than RF counterpart [3,4]. In addition the user "visually" knows whether they will receive location data, unlike RF signal (NFC, WIFI or RFID) might be shielded or faded.

On the other hand, smart handheld devices (e.g. tablet) usage has grown substantially in the last several years for personal and business applications. The devices are anticipated to be effortlessly used for multiple purposes and in a wide range of applications including communications, entertainment, productivity, monitoring and navigation where the last one, navigation application, is expecting to grow rapidly the next few years as human beings entering the smart society era. Therefore, smart devices together with localization sensors are becoming highly integrated to form a newly supporting living-system and they will be mutually developed, well connected and affordable to every user [5].

２．研究の目的

This project aims to study the framework on the development of smart supermarket based on VLC-based smart lighting, mobile application technology and other enabling technologies, including VLC data transmission, video streaming and data processing.

In particular, we aim to develop a prototype of a smart cart, an intelligent version of those usually found in supermarkets, a smart lighting system that support VLC-based indoor localization and data transmission, and a cloud-based infrastructure to provide a personalized customer shopping experience, as illustrated in Fig. 1. When customers visiting a smart supermarket, like the one proposed here, could enjoy the following functions and benefits:

(1) Using a network-connected smart cart in conjunction with a tablet or smartphone running an application with a friendly user interface (especially design for senior citizens), with which they could use secure, on-the-go checkout and even online billing.

(2) Tablet-equipped carts enhanced with sensors developed in this project could estimate their precise location via VLC beacon signals from the available-installed supermarket LED-based energy-efficient lighting system with the additional improvement from ultra-sound positioning.

(3) Thanks to the unique location awareness function, customers could get accurate, prompt and personalized online support and recommendations, or personal assistance from supermarket staff.

(4) The supermarket, based on the location of a cart and customer purchasing status, can display recommendations (including advertisements) on a tablet (visually, aurally, etc.) as the customer is moving along a given aisle.

3. 研究の方法

The project consists of (1) implementation of proof of concept system, (2) protocol design and (3) fundamental studies on enabling technologies for the smart supermarket system, including VLC, ultra-sound positioning techniques, VLC data network, video steaming over mobile network, cloud-based recommendation system, and user experience evaluation.

The methods for project implementation thus include both hardware, software implementation, protocol design and analytical studies with simulation works.

4. 研究成果

The goal of the project is to develop a framework for smart supermarket based on visible light communications (VLC) technology and the smart-device app. In addition, another goal is to study the feasibility of enabling technologies supporting the framework. In summary, the project research is reflected in four main achievements as follow.

First, we designed and implemented a proof of concept of the VLC-based positioning system that includes a smart lighting with built-in location beacon signal, a receiver that can be mounted on smart cart and wirelessly connect to a tablet/smartphone.

Secondly, we developed a framework on the large-scale location identification (ID) and the exchange protocol for the communication between VLC beacon and smart carts, and a cloud-based recommendation software supporting user shopping experience based on sale data analysis using R.

Thirdly, we studied the feasibility of different enabling technologies supporting the smart supermarket environment, including broadband multi-user VLC data network, video streaming over Hypertext Transfer Protocol (HTTP/2) with a special attention to technique to improve the user quality of service and quality of experience, security issues of VLC networks in the context of multiple users.

Finally, we developed a new ultra-sound positing method to improve the accuracy and scalability of VLC-based indoor positioning system.

The result of the project has been disseminated in many different forums, including publications in reputable journals, international conferences, technological fair at the University of Aizu and in the public domain of the Internet (project website).

In total, the result of this 3-year project has been published in nine (09) journal articles, seventeen (17) conference papers and one (01) submitted patent. All publications are accessible in the public domain for the more detail result of the project.

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〔産業財産権

○出願状況（計 1 件）
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