Smart Corridor: Development of Smart Space for Corridors and Public Streets

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Abstract
This paper describes the Smart Corridor project, which offers services in walking spaces by constructing the special infrastructure for it. In a smart corridor, there are public users who have different purposes and situations. First, the issues in constructing such smart infrastructure from various UbiComp experiments are specified. It must have high reconfigurability and extendability, and it must not interrupt any pedestrian's walking. By solving these issues, we construct the prototype of Smart Corridor as our experimental facility in Keio University. The Smart Corridor prototype consists of the frame structure that enables easy installation of devices, various sensors, actuators, and a sensor/actuator management system. In this paper, the overview of the Smart Corridor project is presented and the prototype implementation is explained.

Keywords
Smart Space, Public Space, Ubiquitous Computing, Urban Computing.

ACM Classification Keywords
D.2.6. Software: Integrated Environment. H5.4. Information Interfaces and Presentation: Navigation. I2.9. Computing Methodologies: Sensors.

Introduction

Recent years, there are many projects for constructing ubiquitous computing environment called "Smart Space," which is equipped with many sensors, actuators and indoor location systems. In many cases, smart spaces are realized in houses[1][4], rooms[5][7], offices[2], and other confined spaces. These smart spaces are designed for closed spaces and for supporting specific user activities. In this project, we focus on developing the smart space for a corridor, where people are walking, stopping or passing through. In such a corridor, each user may have different destinations and tasks. In other words, unlike the existing smart spaces, the Smart Corridor needs to support many user activities and must have reconfigurability and extendability for installing various sensors and devices.

By attacking these challenges, we developed a prototype of Smart Corridor that supports various types of UbiComp experiments. The Smart Corridor consists of pre-installed devices and a sensor/actuator management system.

This paper is organized as follows: In Section 2, existing smart spaces is compared with the Smart Corridor. In Section 3, the goal and procedure of the Smart Corridor project is explained. Section 4 presents the requirements for the Smart Corridor. In section 5, we describe the details of the Smart Corridor. In section 6, the future work is discussed, and Section 7 summarizes this paper.

Comparison of Smart Space with Corridor

In this section, classifythe existing smart spaces are classified and compared them with the Smart Corridor.

Smart Room

When designing a smart room, researchers tend to assume specific people and the specific purpose for the room. Therefore, the smart room is equipped with certain devices to be used for the certain purpose. For example, when assuming automatic logging service for a meeting, researchers install cameras or microphones to record the meeting in the smart room.

Smart House

A smart house is a space where certain inhabitants spend their life. Most of the services in the smart house are designed only to support their daily lives. Therefore there are not so much variation in the service.

Smart Corridor

The Smart Corridor is a space which various people use for various purposes, which means, variety of services are expected to be offered in the Smart Corridor. We are considering to provide services such as pedestrian navigation, personal advertisement, artificial panorama and so on.

Smart Corridor Project

We aim to provide services for pedestrians in walking place through the Smart Corridor project. We carry on the project with following three steps. First, we construct the Smart Corridor prototype for experiments of services in a walking place. Second, we experiment various services in the prototype. Third, we construct smart corridors in the various environments and cover the large area with smart corridors working together,which eventually realize "Smart Campus" or "Smart City".

In this paper, we focus on the first step: construction of the prototype. Walking places usually have technical and social constraints. For example, the appropriate way to install devices varies withdepending on the feature of the place. Therefore, Tthe Smart Corridor prototype must simulate many types of walking places that have different constraints.

Requirements for the Smart Corridor Prototype

In this section, the requirements to construct the Smart Corridor prototype are described.

Bare Minimum Devices

Bare minimum devices such as sensors and actuators should be installed in the Smart Corridor prototype. Although such devices are commonly used by many services for the walking space, they must be installed as not to interrupt the users' movement in the Smart Corridor prototype.

Reconfigurability and Extendability

The sensors and actuators in the Smart Corridor should be easily added and removed in order to conduct various kinds of experiments.

Device Management

The Smart Corridor prototype must have a management system of sensors and actuators that have common API to access various devices from the services. The management system provides devices with information such as their locations and data from the sensors. Also, the management system must configure devices automatically when the devices are removed or replaced.

Overview of the Smart Corridor prototype

In this section, the system architecture of the prototype and the current status of the development are explained.

System Architecture

The Smart Corridor prototype consists of an information acquisition part, a service-driving part, and an actuation part as in figure 1.

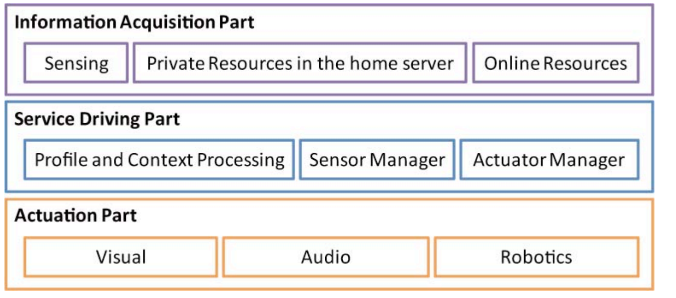

figure 1. System Architecture

It is necessary to sense the state of the Smart Corridor for implementation of context-aware services. In the information acquisition part, the system collects both environmental information and user's condition such as the location and the number of people in the corridor from the installed sensors.
In the service driving part, the system manages devices and provides API for sensor data based on the requirement of the service.
The actuation part is an abstracted platform for output from the services. Every service does not directly output to the actuators, but delegate its output to the actuation part. It arbitrates multiple outputs from various services and dispatch to actuators in the corridor including mobile devices of the users in order not to cause conflicts among outputs and not to disturb movement of people in the corridor.

Prototype Structure

In this subsection, the Smart Corridor prototype that we construct in Keio University Campus is presented. We built the structure of the prototype with a frame called "Smart Infill" and installed sensor nodes and actuators as in figure 2 and 3.

Input (Sensors)		
Type	Detail	Number
Ambient Sensor	Sun Spot & Crossbow Mote	13 & 13
Spherical digital video camera	Viewplus Ladybug2	1
People Counter	SICK LD PeCo 5.5	1
Laser Range Finder	SICK LMS200	1
Environmental Sensor	Crossbow eKo	9

Output (Actuators)		
Type	Detail	Number
LCD Monitor	Eizo 24inch	3
PDP Monitor	Panasonic 65inch	1
Controllable Light	Samsung Sunnix	7
Robotic Sensor	SGI Segway RMP50	1

figure 2. Installed Sensor nodes

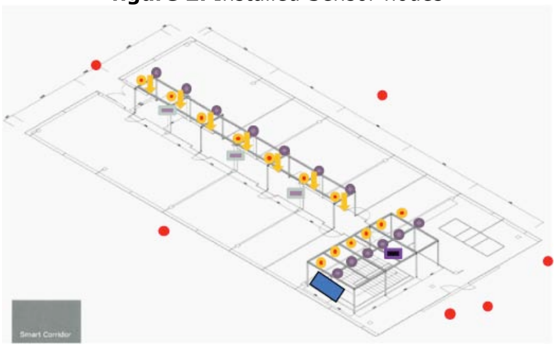

figure 3. Sensor nodes' Installation

- Smart Infill

The Smart Infill is an aluminum frame. It realizes reconfigurability and extendability of the experimental environment. We installed Smart Infill to the stairs and corridors of the university building, and we created a mounter for devices as in figure 4. We can install and remove devices easily with the mounters which we can attach anywhere of the frame.

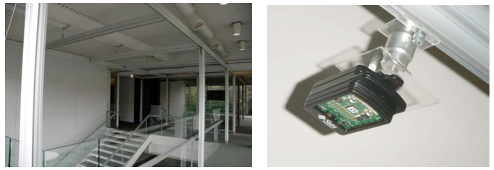

figure 4. Setting of Corridor and Entrance

- Sensors

The information acquisition part acquire user's condition and experimental information. We installed People Counter and Laser Range Finder for analysis of user's condition. People Counter senses the number of people and how crowded the place is. Latter sensor can obtain the position of objects and user's crossing. In addition, we have placed Wireless Sensor Nodes on the Smart Infill. These sensors can acquire environmental information such as acceleration, temperature, and illuminance. Figure 5 shows the setting of the sensors.

figure 5. Setting of Sensors

- Actuators

Actuators in the Smart Corridor is not only that of visual or audible, but also physical. We installed actuators such as Segway RMP50, projectors, wireless LED lights, displays, and speakers (Figure 6). Segway RMP50 is a mobile actuator, which follows the user and provides information. We built a whole floor display with multiple projectors. And we provided an API to control illumination intensity of LED lights through a wireless network for the services. By using these actuators, information can be presented without interrupting the movement of the pedestrian.

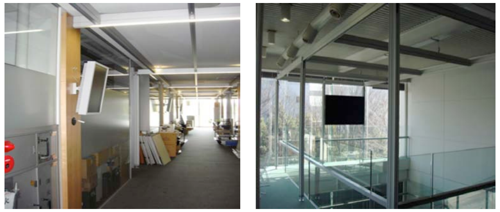

figure 6. Setting of Actuators

- Software

We developed management software of sensor data and actuators. The software maps id of a device with its location visually on the screen when we install devices as in figure 7. It provides sensor data, and manages actuators and device property. In addition, we implemented the database and API to handle sensor data easily. The database stores the sensor data and provides data in XML format via the API. We have developed the system to manage preinstalled devices. We will extend the system to manage joining and removal of devices.

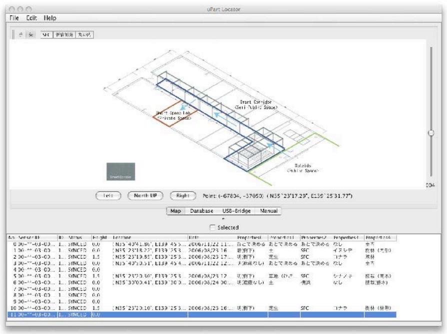

figure 7. Preinstalled Sensor data Management Software

Example experiments and scenario
This subsection presents the example of the experiments and scenario of the Smart Corridor.

- Walking Support

By using the Smart Corridor prototype, various experiments of pedestrian support will be possible. For example, the "Ashi-navi," which is our past work, navigates people with footprints projected on the floor [3]. We can experiment "Ashi-navi" using sensors and projectors preinstalled in the Smart Corridor. By utilizing the environmental information, we can also experiment other navigation systems using additional information such as traffic condition and atmosphere.

- Activity Support

As the activity support services, "Who will be the customer?" project is an example: a robot detects people who are deciding and help them [6]. With the Smart Corridor prototype, experiments of various activity support services are possible. For example, when designing an activity assistance system for amusement parks such as Walt Disney World, you can create a similar environment within the Smart Corridor and conduct experiments there before you actually install the system to the park. We can also experiment assistance of communication on the corridor that shows information on a public display according to the user's schedule or people's conversation.

Future Work

The prototype is evaluated and remaining tasks are discussed here.

Experiments under the various situations
We will experiment services under the various situations such as corridors of offices, passage of a university campus,

sidewalk of the city that are simulated in the Smart Corridor prototype. We can evaluate reconfigurability and extendability of the prototype through the experiments.

Service Roaming Experiment

We will experiment cooperation of the Smart Corridor after the above experiments. Outdoor walking space and public walking space have the technical and social constraint. Therefore, quality and variation of service will be different between each Smart Corridors. To provide continuous service to the user, it is necessary to cooperate each Smart Corridor. Therefore, we will experiment service roaming.

Summary

In this paper, the Smart Corridor project that constructs an infrastructure for providing services in a walking space is described. Because each pedestrian has different purpose and situation, smart corridor must provide various services for many situations.

We constructed the Smart Corridor prototype equipped with reconfigurability and extendability with Smart Infill and sensor/actuator management system. We also installed various sensors and actuators in the smart corridor.

As a future work, we will experiment various systems in the prototype and develop service roaming functionality. Through the Smart Corridor project, we take a step toward “Smart Campus” and “Smart City”.

Acknowledgement

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