Wi-Foto 2: Heterogeneous device controller using Wi-Fi positioning and template matching

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Abstract. Improving usability of heterogeneous devices is important in pervasive computing. We have developed Wi-Foto, which enables users to control such devices by using a tablet PC as a client. Wi-Foto has a user-friendly interface which has device controllers overlaid on a photo depicting the interior of the room where the user is. In order to find the most appropriate photo, Wi-Foto automatically locates the user by Wi-Fi positioning but the localization would often fail because of inadequate accuracy. To solve this problem, we propose Wi-Foto 2, which combines the Wi-Fi positioning with template matching based on a SIFT algorithm. We confirm that the proposed method realizes accurate and fast positioning. Wi-Foto 2 also enables users to seamlessly select photos through hierarchical and panoramic views.

Key words: Smart Computing, Device Control, WiFi positioning, SIFT

1 Introduction

As heterogeneous devices in a room gain network connectivity, developments of novel device control methods, which are more comfortable than direct manipulation and IR remote controls, become active. In the tabletop computing field, device controllers are displayed on a table, and a ceiling camera captures users' gestures. [1] AR (Augmented Reality) systems, which are operated on tablet PCs or smart phones, are user-friendly device controllers.[2] But, they are still not practical because of as follows. In the former, users should be near the table to control devices. The latter approach is unrealistic because markers have to be attached on all devices for the AR systems to recognize the devices. Furthermore, the additional sensors spoil the interior design of rooms.

We have developed a user-friendly device control system, Wi-Foto[3], which has device controllers overlaid on a current room photo. Wi-Fi fingerprints are obtained when the photos are taken, and the photos are stored together with the fingerprints, so that the system can provide a photo of the place closest to the user. Therefore, users can control devices anywhere in the room, and the system needs no devices attached.

Wi-Foto requires a highly accurate indoor positioning mechanism to automatically choose a photo at the user's current location from among many candidates. The most practical methods would be Wi-Fi positioning systems; however,

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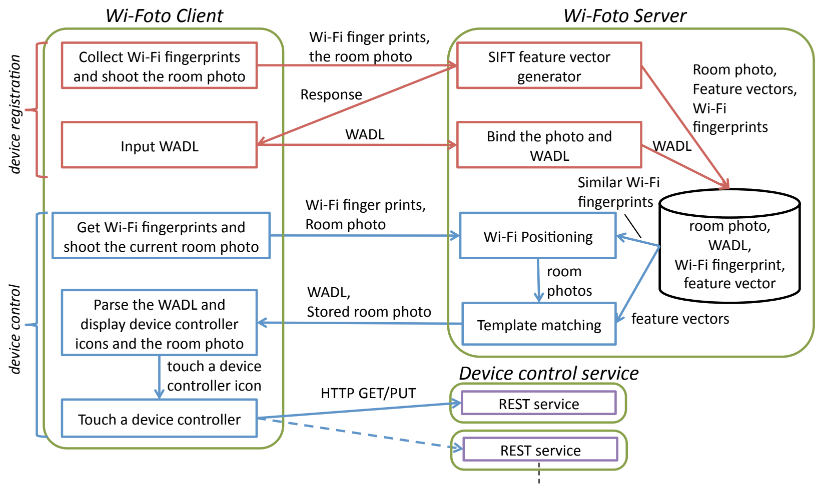


Fig. 1. Design of Wi-Foto 2

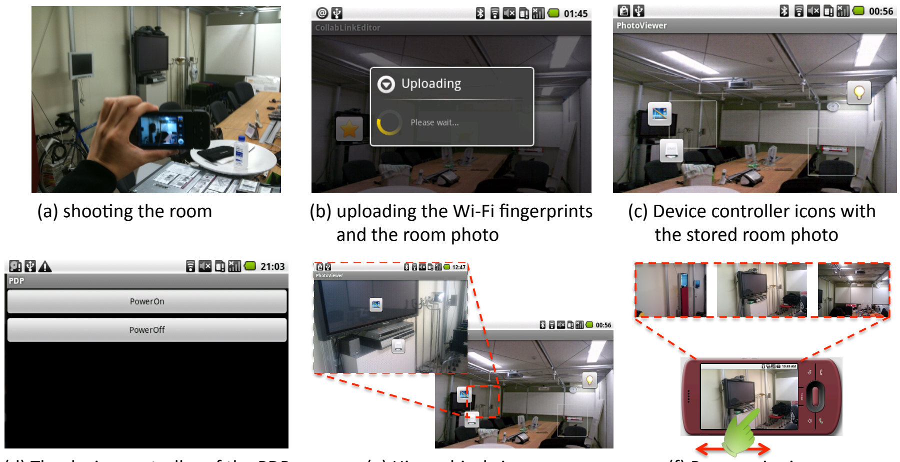
their error of over 10 meters is too large for our purpose, especially when the user is in a large room where several candidate photos are found or when radio waves penetrate the walls around the user. Alternatively the user could manually select a photo but this would be less convenient for the user. Even though there are some higher-accuracy indoor positioning systems, such as those using ultrasonic signals or LED beacons, they have high infrastructure construction costs. It's desirable to realize other positioning methods with no modification of infrastructures.

To solve these problems, we combine Wi-Fi positioning and template matching which utilizes a SIFT (Scale Invariant Feature Transform) algorithm[4]. SIFT analyzes a photo and generates a feature vector which has enough quantity of key points of objects for object recognition. Wi-Foto is in a better condition for template matching method because Wi-Foto needs to have room photos in advance. Furthermore, there is less additional infrastructure cost because the most personal tablet PCs and phones have a camera. Generally, template matching methods become slow when the number of candidate photos increases, and the accuracy decreases when there are many similar candidate photos. By utilizing Wi-Fi positioning to roughly narrow down the candidate photos, we have improved the performance of the template matching.

Furthermore, improved Wi-Foto (Wi-Foto 2) has a new feature: support for hierarchical and panoramic views. These views enable users to seamlessly move to detailed or neighboring photos.

2 Design of Wi-Foto 2

Fig. 1 shows the design of Wi-Foto 2. Wi-Foto 2 consists of the Wi-Foto client and the Wi-Foto server. As heterogeneous devices are RESTful, a Wi-Foto client



(a) shooting the room (b) uploading the Wi-Fi fingerprints and the room photo (c) Device controller icons with the stored room photo

(d) The device controller of the PDP (e) Hierarchical view (f) Panoramic view

Fig. 2. Demo

can get device state and control devices by HTTP GET/PUT methods. Also, the Wi-Foto client discovers Wi-Foto servers by multicast DNS. The Wi-Foto client automatically collects Wi-Fi fingerprints as soon as it is activated.

In the device registration mode, users register device controller with the Wi-Foto server by sending Wi-Fi fingerprints, the room photo and the WADL (Web Application Description Language) of the device control services. The WADL describes how to communicate with a REST service. The Wi-Foto server receives the Wi-Fi fingerprints and the room photo from Wi-Foto client and calculates SIFT feature vectors of the photo. The server stores the Wi-Fi fingerprints and the feature vectors in the DB. Then the server receives the WADL and stores it into the DB.

In the device controller mode, the Wi-Foto client also automatically collects Wi-Fi fingerprints. After shooting a current room, the client sends the Wi-Fi fingerprints and the room photo to the Wi-Foto server. As the size of feature vectors is bigger than a size of a JPEG file, the client sends the server not the feature vectors but the photo. Wi-Fi positioning module receives the Wi-Fi fingerprints, locates the user by calculating similarity of Wi-Fi fingerprints, and chooses several candidates. The template matching module chooses a photo among the candidates by calculating the similarity of their feature vectors based on SIFT algorithm. As all the feature vectors of candidates are stored in the DB, the template matching module doesn't need to dynamically generate feature vectors.

3 Demo

We implemented a Wi-Foto 2 client for Google Android phones. In this demo, a user experiences the quick retrieval of a correct room photo and the user-friendly device control interface. The target room photos and the device control services are set up in advance. Steps for using the client are as follows.

1. Activating the Wi-Foto client.
   The client displays camera image (Fig. 2 (a)) and automatically collect Wi-Fi fingerprints.
2. Shooting the room picture which includes devices.
   After shooting the room, the client sends Wi-Fi fingerprints and the room photo. (Fig. 2 (b))
3. Wi-Fi positioning and template matching.
   After finishing the Wi-Fi positioning and the template matching, the server sends the device controller icons and the room photo back to the client.
4. Displaying the device controller icons and the room picture.
   The client parses the device controller information and overlays the device controller icons on the room photo. (Fig. 2 (c))
5. Controlling devices. (Fig. 2 (d))
   After pressing the device controller icon, the device controller appears.
6. Panoramic and hierarchical view (Fig. 2 (e, f))
   Among new features of the Wi-Foto 2, users can instantly add more photos and create the panoramic and hierarchical views of shots from the camera on the Android smart phone.

4 Conclusion

Toward a high usability heterogeneous device control system, we have improved Wi-Foto by combining Wi-Fi positioning and template matching based on a SIFT algorithm. Furthermore, we have implemented the hierarchical view and panoramic view to enable users to seamlessly reach the target devices. In the future, we will evaluate and confirm that Wi-Foto 2 enables users to easily and quickly control heterogeneous devices. And we will introduce this system into many different environments and evaluate the performance of the Wi-Fi positioning and template matching.

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