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A Location Awareness System using Wide-angle Camera and Active IR-Tag

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Abstract

This paper proposes a new location-awareness system, ALTAIR(Automatic Location Tracking with Active IR-tag) that automatically detects and tracks the location of the mobile PC(Personal Computer) users. IR(InfraRed)-tag is stably detected and distinguished by IR filtering camera. Combination of the IR-tag and wireless LAN (Local Area Network) enables ALTAIR to control the IR-tags through the network to perform stable tracking for multiple users. The position of the detected IR-tag and its network information (e.g. IP address) are associated with each other by controlling the emission pattern of the IR-tag in turn. ALTAIR starts to aware the user's position when the user enters the system area, using DHCP(Dynamic Host Configuration Protocol) service. Our experiments show the effective performance to tracking and recognize the users' positions in an office environment.

1 Introduction

It becomes more and more common to use the personal computers (PCs) regardless of the place recently as the mobile IT(Information Technology) devices such as the cellular phones and PDA (Personal Digital Assistant) spread widely and the service of the wireless network starts in new locations;cafes, airports, sporting arenas, public libraries in the town. Therefore, people can visit any place with their mobile PCs with network connection and may need to refer some information related to the location where the user is standing right now.

Our aim is to provide a location service for the mobile PC users in the facilities including the office buildings, the shopping moles and so on. GPS (Global Positioning System) is a powerful location method, but the public network services like "Hotspot", for instance, are implemented within the buildings where out of the reach of GPS in many cases. For indoors location, there are also some methods to acquire people's position or behavior in a room [1]. Most of the methods using color images from a camera have a limit in the stability of position detection or user extraction by using matching processing of a color [2–4]. Furthermore, each user is required to do an explicit log-in operation, for example typing their names and passwords, so that the system starts to aware and identify he/she. And the method using the combination of the transmitter and receiver of an electric wave or an ultrasonic wave, it is necessary to install many sensors, while highly precise position detection is possible [5, 6]. We propose a new framework of the location system to locate and identify the mobile PC users without "log-in operations to be watched", based on a ubiquitous mobile computing environment. We introduce a combination of the wide-angle camera and the IR(InfraRed)-tags which emit IR light. IR-tags are connected to the system through the wireless network and the lighting patters of the tags can be controlled by the system. Our approach is to employ the wide-angle camera for both spatial and temporal process. The spatial process traces the multiple users' positions and the temporal process identifies each user and associates with his/her position.

In this paper, we describe the details about the process flow in the proposed system, ALTAIR in Section 2. Our implementation and experimental setup are shown and discuss the performance of the system in Section 3, then conclude in Section 4.

2 ALTAIR System

2.1 Proposed method

Our system, named ALTAIR(Automatic Location Tracking with Active IR-tag), has a hierarchical configuration(Figure 1). The Location Server is on the top level and manages the location information for the all users in the whole area. According to the demands from the other application systems, information is sent to an application server which performs location related services. Local Location Manager(LLM) locates and integrates the users' positions in a section or a room, where users are carrying the mobile PCs. A LLM always communicates several Tag Detectors(TD). A TD captures the image sequence from a wide-angle camera to detect the lights from the IR-tags. The positions and lighting patterns of the IR-tags are transmitted to the LLM. Several camera systems of TDs are installed in each room. LLM manages and renews a list of the users' entry, according to the communications to the DHCP server and the TDs. To identify the users, LLM sends massages to a IR-tag to blink in order to associates the blinking position with corresponding IP address.

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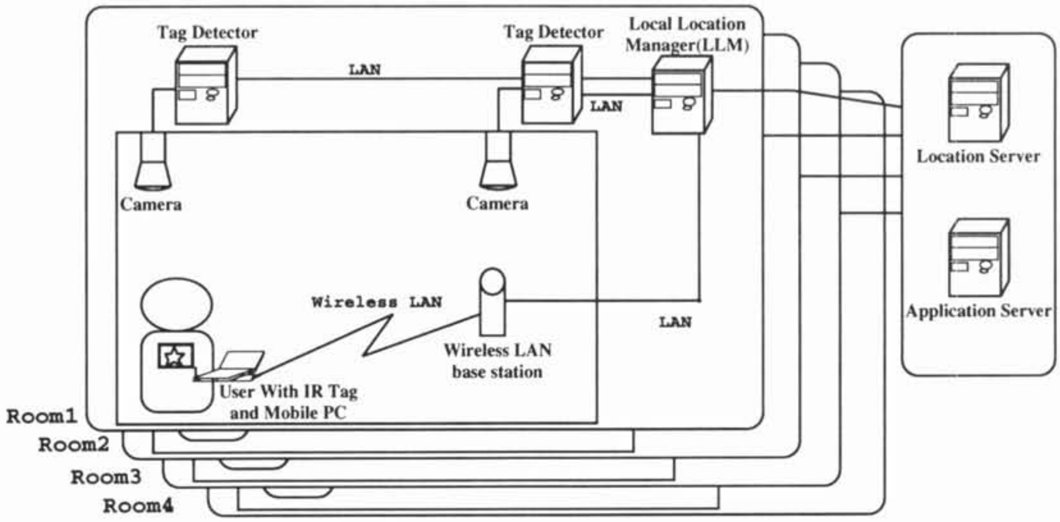

Figure 1: System Overview

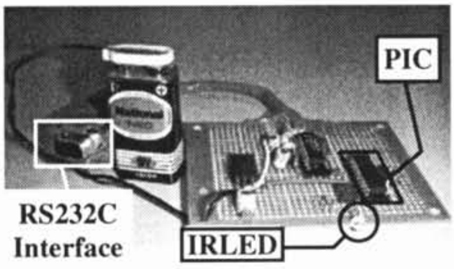

Figure 2: IR tag(prototype)

2.2 IR-tag

IR-tag is a small-sized marker with a IR LED which is controlled by the mobile PC though a serial connection, RS232C. The lighting pattern of the IR LED on the tag is changed according to the massages that the PC receives via network from the LLM. Our proto-type IR-tag is about 10cm square size and easily put with the mobile PCs (Figure 2).

2.3 IR wide-angle camera

Our camera system is constructed with color CCD camera, optical IR-filter and wide-angle lens. Since IR-filter shuts off visible light and transmits IR(infrared) light, our camera system can take images of near-infrared range. And a wide-angle lens, we use a fish-eye lens, helps a camera cover large area. Figure 3 shows comparing image of visible range and infrared range. Both of images contains the user who is 5m away from the camera. It is capable to extract the light from the IR-tag without complicated image processing, while visible image needs it or cannot extract user.

2.4 Tag Detector(TD)

Tag Detector(TD) tracks lights of IR-tag from the image sequence of the IR wide-angle camera and detects that one of the IR-tag is blinking. The TD sends a message to the LLM to inform the light positions in the world coordinate and which light blinks. The flow of detailed processing is as follows.

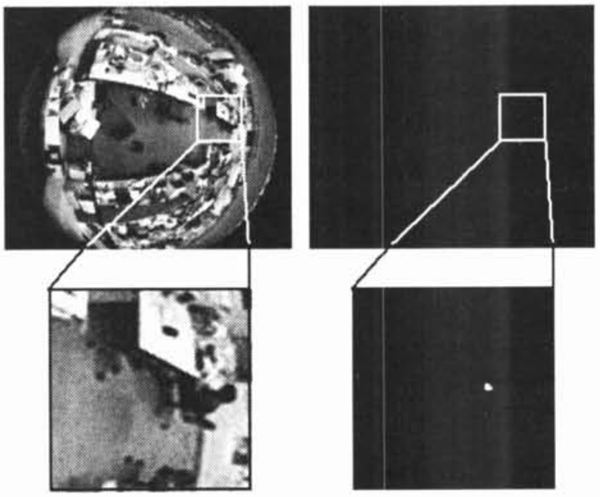

Figure 3: Captured images with wide-angle camera: visible range(left),infrared range(right)

1. Extracting lights: The TD captures the image of the IR wide-angle camera. Thresholding and labeling technique, the lights of IR-tags are extracted. Output of this step is the light positions in camera coordinate.
2. Tracking lights and detecting blinks: The TD updates a list of lights on each frame. The list contains a light position in the camera coordinate, a lighting state flag, and a blinking counter for each detected IR-tag. The data of the list is updated by searching the light positions in the neighbor area between consecutive frames and checking the lighting state("off/on"). The number of the state transition from "off" to "on" is counted up as the number of the blink.
3. Calculating position: The light positions are captured and expressed by the camera coordinate system. In order to register the information from several TDs that have different camera systems, transformation from camera coordinate to world coordinate is necessary. We define the coordinates as Figure 4 shows. Using data sheet of the wide-angle lens, θ (the angle of lens axis and IR tag) can be approximated from l (the

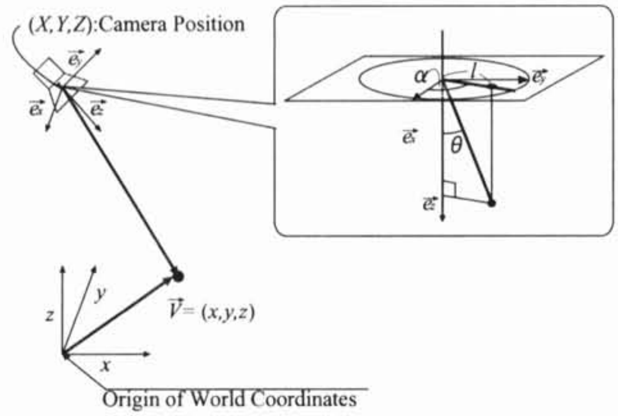

Figure 4: Camera coordinates and World coordinates

distance from the center in a picture to light points). Then, vector $\vec{V}$ is expressed as

$$\vec{V} = (X, Y, Z) + k(\vec{e_x} \sin\theta\cos\alpha + \vec{e_y}\sin\theta\sin\alpha + \vec{e_z}\cos\theta)$$

with basis unit vector of camera coordinate $\vec{e_x}, \vec{e_y}, \vec{e_z}$ and camera position (X, Y, Z). In order to determine the 3-dimensional position of lights, the lights' height(z) has to be assumed uniformly.

Sending message: Every several frames, for example 10 frames, TD calculates position of all light points and sends message to the LLM. The message contains positions of lights in the world coordinate and information of blinking or not.

2.5 LLM(Local Location Manager)

A LLM merges and integrates the information sent from the TDs that cover an assigned section or a room and update the user map. The information from multiple TDs are buffered and merged by a LLM. Comparing the buffered data with the latest map, tracking of the each user's position is performed by nearest neighbor search. A LLM has a queue which contains all the users entry in the section expressed by their IDs. LLM sends a request message to a user's IR-tag to blink in a specified manner. The user to sent the message is chosen according to the queue. If the blinking LED is detected by the TDs, LLM can identify the user and successfully renew the location. Even in the case after a user is completely lost from the TDs because of visual occlusion, for example, the location can be recovered by this "roll call" strategy.

When a new user comes into a system area, the user's Mobile PC acquires the information for connecting with LLM which manages the area, and with network environment, such as IP address using DHCP service etc. Based on the information acquired, a user's Mobile PC connect to LLM. LLM receives the connection demand from a user, attaches ID to a new user, and push the new user's ID to blinking queue. A new user is distinguished preferentially and tracking is started.

3 Implementation and Experiments

In order to verify whether a system can realize tracking and distinction of two or more users as we described above, we implemented one section of the proposed system and performed an experiment in an office environment.

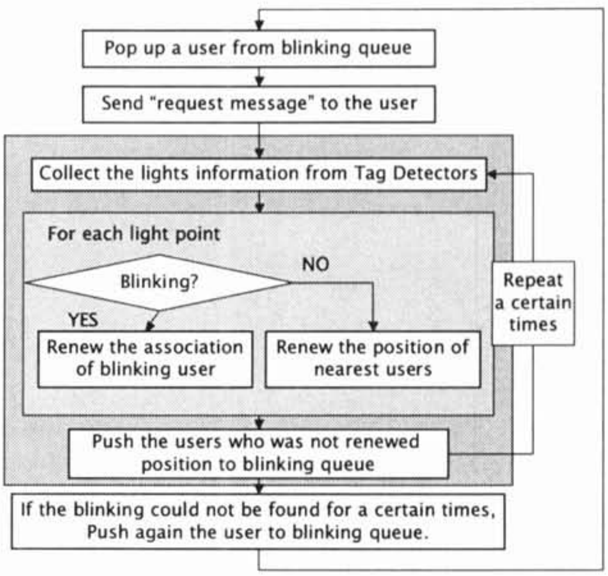

Figure 5: Flow of LLM

3.1 Prototype Location System

As shown in Figure 6, we settled target area is 6m-square. Two IR wide-angle cameras(WATEC 202D, 640x480 pixels) with fish-eye lenses were installed in the area so that they face each other. The height of the cameras are about 2.5m and depression angles are about 45 deg. In the target area, an LLM and two TDs were implemented with the PCs listed in the Table 1. The IP addresses for the PCs are fixed in this experiment. We performed manual calibration for camera setup such as positioning, settling the center and the range of the camera images. IR LEDs (5mm ϕ, λ=880nm, beam angle:40 deg.) are used for the Tags. The blinking pattern of the IR-tag was settled as the repetition of 50ms on and 50ms off, or 10Hz. The height from the floor of IR tag was assumed to be 1.2m for calculation of the positions. The mobile PCs are carried so that LED might always turn to the direction of one of the cameras.

3.2 Results

Figure 7 shows the output of the LLM and unprocessed camera image for comparison. Each TD captured images with the speed of 18-22fps and stable count of the blinking required the image sequence of about 13 frames. Updating rate of the users' position

	CPU	RAM
LLM,Tag Detector(1)	Pentium4 2.0GHz	512MB
Tag Detector(2)	Pentium4 1.8GHz	512MB
Mobile PCs	PentimuII 400MHz	128MB

Table 1: Specifications of the PCs

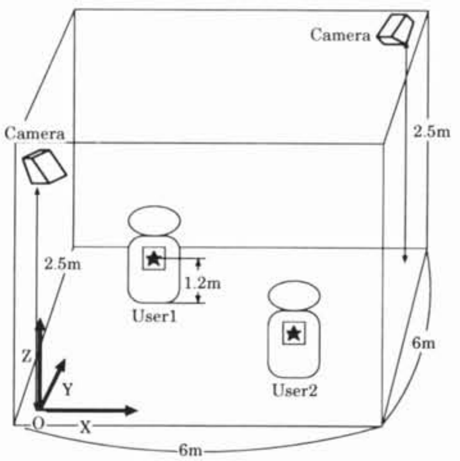

Figure 6: Experimental Space setup

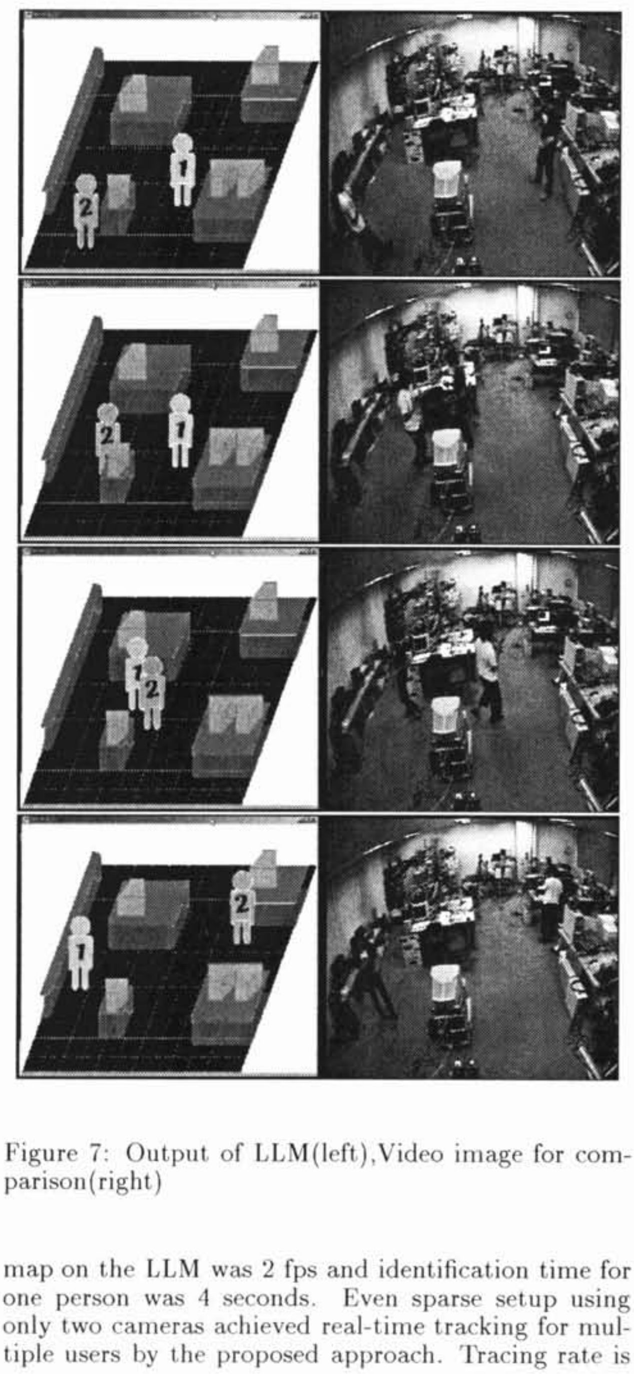

Figure 7: Output of LLM(left),Video image for comparison(right)

map on the LLM was 2 fps and identification time for one person was 4 seconds. Even sparse setup using only two cameras achieved real-time tracking for multiple users by the proposed approach. Tracing rate is not fast, but "roll call" strategy ensures the identification of the individual IR-tags and we consider that the performance of the system is efficient for the office workers location. In the Figure 7, two users walk across changing the directions. Visual occlusion may occur and tracking error to exchange the users may happen but, eventually our system performed correct tracking and mapping.

On the other hand, some problems were found in the system setup. We need to establish systematic method to calibrate the camera systems otherwise the measurement error of the position was up to 1m at maximum. The system also suffered from frequent occlusion because of the directivity of IR LEDs. We are going to improve the IR-tag emission, designing the arrangement of the multiple LEDs.

4 Conclusion

We have proposed ALTAIR system and implemented the core part to identify and grasp positions of the mobile PC users using IR-tag and wide-angle cameras. As the experimental results show the ALTAIR system is capable of managing information of two or more users in real-time process and recover from the tracking error because of visual occlusion and so on. Our approach is practical and verifiable. Our future work is to implement the system to connect more sections to cover larger area such as the whole building and activate an organized application in an office environment.

Acknowledgments

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