PROPOSAL OF TRACKING LAN ANTENNA USING IMAGE SENSOR

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ABSTRACT

This paper proposes a wireless LAN antenna system that tracks an object automatically by using image-based tracking. The proposed system consists of a camera and a pan-tilt unit in addition to a directional wireless LAN antenna. The camera and the directional antenna are set in same direction and they are set on the pan-tilt unit. A target object which has a wireless LAN receiver is tracked by using images captured by the camera. And the directional antenna faces in same direction as the camera by the pan-tilt unit. Therefore, the directional antenna keeps pointing the receiver, and a transmitting efficiency is improved. A result of a fundamental experiment shows that a receiver attached to a flying airship was tracked by a prototype of the proposed antenna system. The airship flied about, and the proposed antenna system was set on a roof of a building. The experimental result indicates an effectiveness of the proposed system compared to the conventional directional LAN antenna.

Keywords: wireless LAN, directional antenna, object tracking, pan-tilt unit

1. INTRODUCTION

There is a communicating situation with an object which moves around broad area over a wireless Local Area Network (LAN). One example of such situations is a communication between an airship and an access point on a ground under a disaster [1][2][3]. Under such situation, It is desirable that the communication is stable and keep high transmitting efficiency. Directional wireless antennas have better transmitting efficiency than non-directional antennas when the antenna faces a target object accurately. In case that the directional antenna is used for communicating with the moving objects, it is important that the directional antenna keeps tracking the target objects for stable communication.

We propose a wireless LAN antenna system that tracks an object automatically by using image-based tracking. The proposed system consists of a camera and a pan-tilt unit in addition to a directional wireless LAN antenna. The camera and the directional antenna are set in same direction and they are set on the pan-tilt unit. A target object which has a wireless LAN receiver is tracked by using images captured by the camera. And the directional antenna faces in same direction as the camera by the pan-tilt unit. Therefore, the directional antenna keeps pointing the receiver, and a transmitting efficiency is improved.

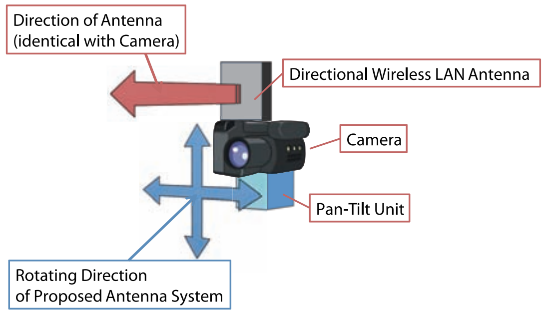

Fig. 1: An overview of the proposed system. The proposed system consists of a camera and a pan-tilt unit in addition to a directional wireless LAN antenna.

In this paper, two fundamental experiments with an access point that is loaded onto a flying airship and an access point which is placed on a roof have been performed. First, a transmitting efficiency over Transmitting Control Protocol (TCP) and User Diagram Protocol (UDP) was evaluated. Second, a telepresence application was demonstrated over the LAN by using the proposed system. The experimental results has demonstrated an effectiveness of the proposed system.

2. PROPOSED SYSTEM

We propose a wireless LAN antenna system for improving a transmitting efficiency of a communication with an object which moves around broad area. The detail of the proposed system are described below.

2.1 System Overview

Figure 1 shows an overview of the proposed system. The proposed system consists of a directional wireless LAN antenna, a camera and a pan-tilt unit. The camera and the antenna are set in same direction, and they are set on the pan-tilt unit.

A target object which has a wireless LAN receiver is tracked by using images captured by the camera, and the pan-tilt unit is rotated in order to keep the object on the center of the captured image. Then the directional antenna

(a) (b)

Fig. 2: Extracting flying object. (a) An image captured by the camera which is attached to the system. A cross on the image shows a gravity of each extracted region. (b) Extracted regions in case that $L_t = 255$ and $d_t = 0$.

Fig. 3: A prototype of the tracking wireless LAN antenna. The system consists of a camera, a directional wireless LAN antenna and a pan-tilt unit. The directional antenna faces in same direction as the camera by the pan-tilt unit.

faces in same direction as the camera by the pan-tilt unit. Therefore, the directional antenna keeps pointing the receiver, and a transmitting efficiency is improved.

2.2 Tracking an Object

The captured image is converted into L*a*b* color space. Next, an output lightness L_o of each pixel is binarized as

$$L_o = \begin{cases} 255 & (L > L_t) \cap \left(\sqrt{a^2 + b^2} < d_t\right), \\ 0 & \text{otherwise}, \end{cases} \quad (1)$$

where L, a and b are values of L*, a* and b*, respectively. And L_t and d_t is a constant. The largest three continuous regions in the binarized image are extracted. Figure 2 (a) is an example of the captured image, and (b) is extracted regions. Then the pan-tilt unit keeps the gravity of the extracted regions at the center of the captured image by rotating the camera and the antenna.

3. EXPERIMENTAL RESULTS

An experiment was performed with a prototype of the proposed antenna system. First, a transmitting efficiency using the proposed system was compared to the transmitting efficiency using non-tracking antenna over Transmission Control Protocol (TCP) and User Datagram Protocol (UDP) over IEEE 802.11g. Next, a telepresence application was demonstrated via the network which is using the proposed system. The experimental results are described below.

3.1 Experimental Environment

Figures 3 and 4 show a prototype used in the experiment. A camera is Point Grey Research Dragonfly. The resolution of a captured image is 1024×768 pixels. Japan Radio JRL-720E was used as an access point. A directional wireless LAN antenna used in the experiment is Japan Radio NZA-640. A directivity angle in a horizontal and a vertical of the antenna are $65°$ and $60°$, respectively. A distance between the optical axis of the camera and the center of the antenna is 100mm, and the camera and the antenna is aligned in parallel. A pan-tilt unit is Directed Perception PTU-D46-70, whose rotating angles are $318°$ horizontal and $78°$ vertical. Figure 5 is an overview of the airship used in the experiment. An overall length of the airship is 9 meters. An access point (Japan Radio JRL-720E) and a non-directional wireless LAN antenna, and a laptop computer were loaded onto the airship.

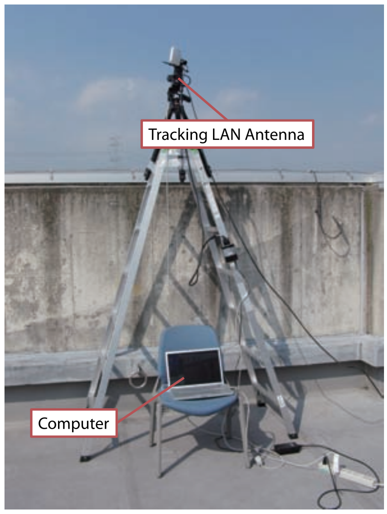

Fig. 4: An overview of the prototype which is placed on the rooftop of the building.

Figure 6 is a map of an experimental environment. The prototype was set on the roof of a seven-storied building, and temporary parking apron for the airship is set up on a playground. The distance between the antenna and the apron is approximately 150 meters. Figure 7 is a scene from the roof on which the antenna was placed. A maximum altitude for the flight is 150 meters, because it is restricted by Japanese Aviation Law. There are no obstacles between the antenna and the flight area for the airship.

The experiment was performed over three days. Table 1 shows the weather of each experiment day [4].

Table 1: A weather, a temperature, a humidity and a maximum wind direction/speed of each experiment day. A value of the temperature and the humidity the wind speed are an average of each entire day.

	Weather	Temperature (°C)	Humidity (%)	Maximum wind	
				Direction	Speed (m/s)
Day 1	Fine	22.3	70	SW	2.9
Day 2	Fine	21.5	60	NNE	1.8
Day 3	Cloudy, Rain later	16.0	95	S	3.0

Fig. 5: An airship used in the experiment. An overall length of the airship is 9 meters.

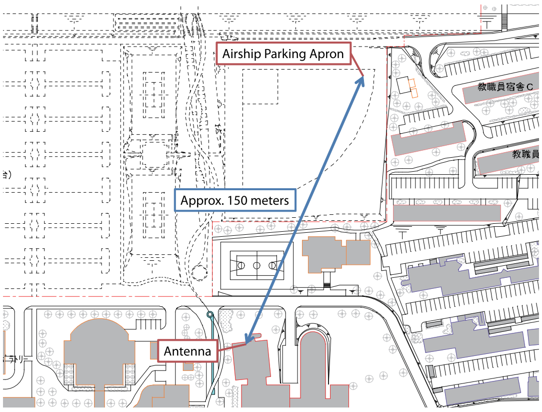

Fig. 6: A map of an experimental environment. The distance between the airship parking apron and the roof on which the antenna is placed is approximately 150 meters.

3.2 Throughput Measurement Over TCP/UDP

Transmission efficiency over TCP and UDP was evaluated by the proposed system. Throughput and Round Trip Time (RTT) between two access points were measured: the one is attached to the directional antenna on the roof, and the other is loaded onto the airship.

The experiment was performed in three situations: the airship was landed, not-tracked and tracked. When the airship is landed, the antenna faces to the airship. And the direction of the antenna is fixed to the center of the flight area when the airship is not tracked. Table 2 shows experimental results over UDP in case that airship was landed, not-tracked and tracked. The experiment was performed at the Day 1.

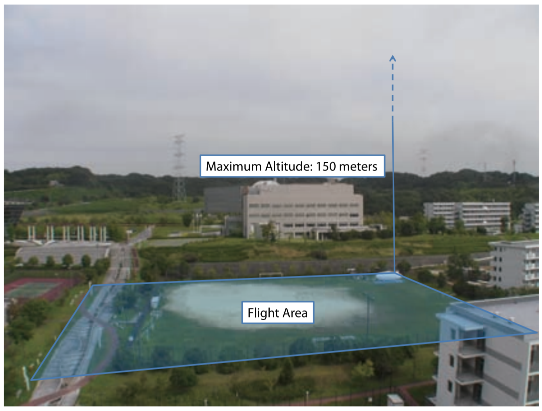

Fig. 7: A scene from the roof on which the antenna is placed. A maximum altitude is 150 meters limited by Japanese Aviation Law. There are no obstacles between the antenna and the airship.

Table 3: Throughputs over TCP in case that the airship was landed, not-tracked and tracked. The measurements were performed at the Day 2.

Status	Throughput (Mbps)	Running time (sec)
(Landed)	(1.52)	(10)
Not-tracked	**0.93**	324
Tracked	0.50	258

Experimental result in case of TCP is also shown in Table 3. The experiment was performed at the Day 2. Note that Japan Radio JRL-710AP2 was used as the access point on the roof only in this experiment.

In addition, an RTT in the two cases, not-tracked and tracked, was measured. Table 4 is a result of the experiment. An average, a minimum and a maximum of the RTTs in case that the airship was tracked are smaller than the case that the airship was not-tracked.

3.3 Demonstration of Telepresence Using the Proposed System

A telepresence application was demonstrated over the LAN by using the proposed system. The demonstration was per-

Table 2: Experimental results over UDP in case that the airship was landed, not-tracked and tracked. A throughput, a jitter and lost/sent packets were measured. All measurements were performed at the Day 1.

Status	Throughput (Mbps)	Running time (sec)	Jitter (msec)	Lost/Sent packets	Sent rate (%)
(Landed)	(1.02)	(50)	(3.774)	(115/4459)	(97.49)
Not-tracked	1.02	267	3.547	721/23808	97.06
Tracked 1	**1.03**	300	**0.844**	469/26751	**98.28**
Tracked 2	1.02	130	5.100	339/11650	97.17

Table 4: An RTT in case that the airship was landed, not-tracked and tracked. The measurements were performed at the Day 2.

Status	RTT (msec)		
	Average	Min	Max
Not-tracked	6475.622	1.769	26263.065
Tracked	**4017.807**	**1.697**	**21473.106**

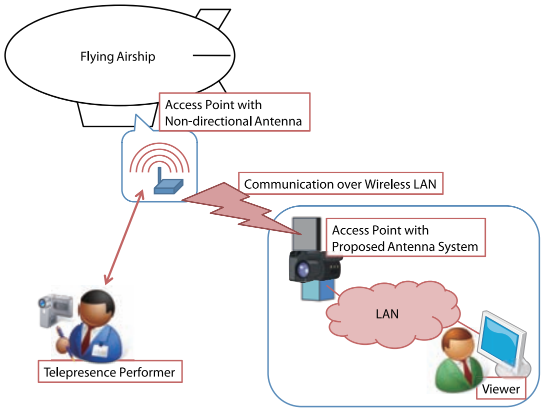

Fig. 8: System for demonstrating a telepresence application. The airship hovers above a telepresence performer who has an omnidirectional camera, and the prototype of the antenna is placed on the roof of the building. Captured images which is captured by the performer are sent via the network. A viewer can see a scene of remote location with a head-mounted display.

formed at the Day 3 in Table 1. Figure 8 is an overview of a system for demonstrating the telepresence application. The airship hovers above a telepresence performer who has an omnidirectional camera, and the prototype of the antenna is placed on the roof of the building. Captured images which are captured by the performer are sent via the network. Viewers can see a scene of remote location with a head-mounted display. Figure 9 (a) shows the performer, and (b) shows the viewers at the demonstration.

4. CONCLUSIONS

We have proposed a wireless LAN antenna system which has a camera and a pan-tilt unit in addition to a directional LAN antenna. The proposed method tracks the moving object automatically, and it improves a transmitting efficiency of the network in most cases. The proposed method is suitable for a communicating situation with an object which moves around broad area over a wireless LAN. Experimental results have demonstrated an effectiveness of the proposed method. In addition, an application of a telepresence has performed.

(a) (b)

Fig. 9: A result of the demonstration. (a) The telepresence performer who has an omnidirectional camera and wireless LAN device. (b) Viewers who wear a head-mounted display. The viewers can see a scene in which the performer is.

Future work will aim at improving the method for tracking objects. There are no obstacles between the proposed antenna system and the object in the experiment. It is desirable that the method has an occlusion robustness.

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