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**Paper:**

# LED Panel Detection and Pattern Discrimination Using UAV's On-Board Camera for Autoflight Control

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**The UAV flight control method we propose uses LED panels and a video camera on the UAV. Specifically, the LED panel displays patterns related to the UAV commands and blinking patterns for panel detection. A panel detection process based in UAV video camera images uses the frequency of green blinking as a cue for panel detection, then command patterns are distinguished and the UAV performs tasks based on this pattern (command). In experiments we performed for panel detection and discrimination using the UAV, we confirm the effectiveness of the proposed method for autoflight control.**

**Keywords:** UAV, LED panel, auto flight control, pattern discrimination, Fourier transformation

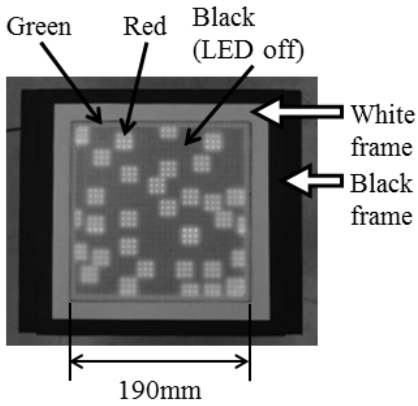



**Fig. 1.** LED panel.

## 1. Introduction

Unmanned aerial vehicles (UAVs) are used in tasks such as aerial photography, agricultural chemical spraying, disaster relief, and transporting baggage. As UAVs carry heavier loads and fly longer distances, the concern arises that accident may be caused because of mistakes in control or unreached radio waves, making it necessary to develop UAV autoflight control system that ensures safer, stabler flight.

The communication system we propose for the UAV uses an LED panel and on-board camera to develop an autoflight control system. The visible light communication system [1, 2] is usually used in digital signage or intelligent transport systems (ITS) [3], but applying visible light communication to UAVs has not been discussed.

In a previous study, we discussed pattern discrimination [4–6] in which the LED panel displays arbitrary command-related patterns (we call them "AR markers" [7]). The LED panel also displays QR codes and micro QR codes in which arbitrary data is embedded. LED panel patterns are determined from LED panel images captured by the UAV's on-board camera. Using LED panel images, 3D position data is also estimated. Global positioning systems (GPS) are generally used to acquire a UAV's position data, but we confirmed that 3D position data of LED panel images is estimated more accurately than by GPS.

In our previous studies, we assumed that LED panels appeared in captured images. We also assumed that LED panels were distributed sparsely on the ground, building roofs, etc., so UAVs must first detect LED panels. The LED panel detection method we propose uses blinking patterns with a frequency. This pattern is displayed on the LED panel with an AR marker simultaneously. We configure an LED panel detection and pattern discrimination system using a UAV, demonstrating the effectiveness of our proposed method by moving the UAV based on discriminated patterns.

In the later of this paper, our system is configured as shown in Section 2. In Section 3, we discuss the overall flight control system, and propose LED panel detection and discrimination methods. The experimental results are shown in Section 4. And, finally, we conclude this paper in Section 5.

## 2. System Configuration

### 2.1. LED Panel

**Figure 1** shows the square indoor-use LED panel used in this study. This panel is 190 mm on a side. The panel has 32-by-32 full-color LEDs. The black and white frames surrounding the LED panel are used to detect this

**Fig. 2.** UAV (AR.Drone 2.0).

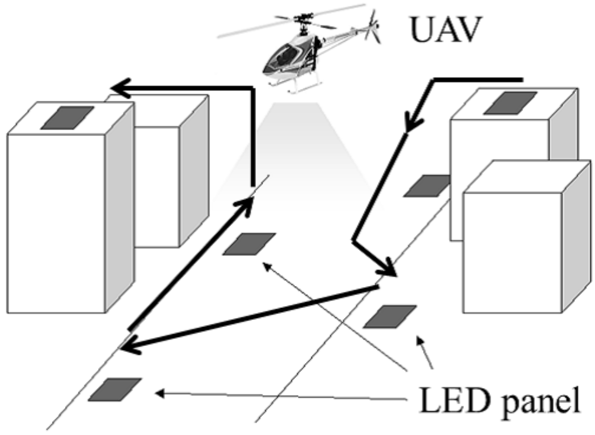



**Fig. 3.** UAV autoflight control system.

panel in captured images.

As shown in **Fig. 1**, 124 LEDs on the four sides of the LED panel blink in green at a predetermined frequency. The 30-by-30 LEDs inside them display AR markers (arbitrary patterns) in red. In experiments, AR marker patterns (commands to the UAV) are changed at a predetermined period. A microcomputer board controls LED panel display and blinking.

### 2.2. UAV

The AR.Drone 2.0 quadcopter (Parrot Inc.) [a] we use as the indoor UAV (**Fig. 2**) has two color cameras in front and below, but only the lower camera is used in this study. Resolution is 640-by-360 pixels, and no auto focus or zoom functions are used.

The AR.Drone is connected via Wi-Fi to the PC and is controlled automatically by a PC program. Camera image capture and transmission and rotor flight control are performed by the AR.Drone's microcomputer (flight controller). The PC receives captured images and detects the LED panel and discriminates among patterns as shown in the next section. To control AR.Drone flight, the PC sends commands corresponding to discrimination results to the AR.Drone, e.g., to go forward, backward, rise, etc. In this study, PC software uses the open source CV Drone library [b] to receive captured images and to send commands to the AR.Drone.

Any delay that may occur in image transmission from the AR.Drone to a PC is very short and does not influence processing, and we confirmed that images captured by the AR.Drone are streamed to the PC at 60 frames per second.

## 3. UAV Control Method Using LED Panel

### 3.1. Flow of UAV Control

In this section, we outline our UAV flight control, as shown in **Fig. 3**, assuming that LED panels are located at points along the UAV flight path. In each LED panel position, the UAV performs some tasks based on the pattern displayed on the LED panel. All LED panel positions are predefined and known and the UAV is assumed to be able to flight near enough to detect the LED panel by using GPS or some other system. The UAV's 3D location is determined from the LED panel image, so using enough LED panels on the ground and building roofs while simultaneously discriminating among multiple LED panels possibly eliminates the need for GPS and other positioning systems. We do not, however, discuss such methods from the viewpoint of facilities cost.

In one application of this system, aerial photography surveillance could be implemented so that the UAV goes around LED panels and take some photographies of indicated directions on LED panels.

The following steps show the task we propose for the UAV at one LED panel in our flight control system:

- *Step 1:* Based on GPS information, the UAV flies near an LED panel. Here we assume that the UAV gets closer to a radius of less than 10 m and an altitude of less than 20 m from the LED panel, although we do not discuss this is in this paper.

- *Step 2:* The LED panel detection.
  The UAV hovers and takes images using its on-board camera. Using the method discussed in the next section, the existence of the LED panel is checked in input images.

  - *Step 2-a:* If the LED panel is not detected, the UAV is moved based on predefined rules and iterated from Step 2.
  - *Step 2-b:* If the LED panel is detected but its position is peripheral to images, the UAV is moved to position the LED panel in the center of the camera image, and iterated from Step 2.
  - *Step 2-c:* If the LED panel is detected and its position is at the center of the camera image, go to Step 3.

- *Step 3:* Take an image of the LED panel again, and determine its pattern as shown in Section 3.3.

- *Step 3-a:* If the displayed pattern is determined, the UAV performs pattern-related tasks. Iteration then proceeds from Step 1.
- *Step 3-b:* If the displayed pattern is not discriminated, pattern discrimination proceeds again from Step 3. After this process is iterated a predefined number of times, iteration then proceeds from Step 1 if the displayed pattern cannot be discriminated.

We detail Steps 2 and 3 in the sections below.

### 3.2. LED Panel Detection

LED panel is detected from images captured by the UAV. The detection cue is the pattern blinking in green on the LED panel. Let $f_p$ be the blinking frequency of the green pattern.

- *Step 1:* Image capture and pixel extraction.
  - *Step 1-1:* The UAV's on-board camera takes an RGB color input image. Let image number be $i$, and record capture time be $t(i)$. The capture time of the first image is set to 0 ($t(0) = 0$).
  - *Step 1-2:* Convert color space in the input image from RGB to hue, saturation and luminance (HSL) [8].

    Set the color parameters of $H$, $S$ and $L$ to $H_{\max}$, $H_{\min}$, $S_{\max}$, $S_{\min}$, $L_{\max}$, and $L_{\min}$. These are the ranges of colors needed to extract a specific color pixels in an input image. (In this method, color parameters are predefined for the individual colors desired. In this step, color parameters are set to extract green pixels.)

    Extract green pixels from the input image by color parameters. A binary image $B_i(x,y)$ sets extracted green pixels as 1 and others as 0, and the number of green pixels as $g_p(i)$.
  - *Step 1-3:* Iterate $N_p$ times from Step 1-1 to Step 1-2, letting $N_p$ be a predefined number with a power of two.
  - *Step 1-4:* Record the processing time from Steps 1-1 to Step 1-3 as $T_p$.
- *Step 2:* Let $\tilde{g}_p(j)$ be a new green pixel number distribution. This is estimated from $g_p(i)$ by resampling at each time $\Delta t$ $(= T_p/N_p)$ in linear interpolation:

  $$\tilde{g}_p(j) = (1-p)\cdot g_p(i) + p\cdot g_p(i+1) \quad \ldots \quad (1)$$

  Index $j$ is assumed as follows:

  $$t(i) \leq j\cdot\Delta t < t(i+1) \quad \ldots\ldots\ldots \quad (2)$$

  and

  $$p = \frac{j\cdot\Delta t - t(i)}{t(i+1)-t(i)}. \quad \ldots\ldots\ldots \quad (3)$$

  In $\tilde{g}_p(j)$, index $j$ is from 0 to $N_p - 1$.
- *Step 3:* Apply the Fourier transformation to $\tilde{g}_p(j)$, estimate maximum amplitude $a_m$ and frequency $f_m$ and phase $\phi_m$ corresponding to $a_m$. Blinking frequency $f$ of the LED panel in the input image is estimated from these values as:

  $$f = \frac{f_m}{T_p}. \quad \ldots\ldots\ldots\ldots\ldots \quad (4)$$
- *Step 4:* If the following condition is satisfied:

  $$(a_m > th_a) \wedge (f_p - d_f < f) \wedge (f < f_p + d_f) \quad (5)$$

  we conclude that the LED panel exists in the input images. That is, the LED panel is detected. In Eq. (5), $a_m$ (amplitude) is treated as the number of green pixels in input image sequences and $th_a$ is the minimum green pixel number used to detect the LED panel. If $a_m \leq th_a$ then, we can consider that the LED panel does not exist in input image sequences. $f_p$ is the true blinking frequency and $d_f$ is a margin such that estimated $f$ is approximately equal to $f_p$. In later experiments, we assign 1.0 to $d_f$.

If Eq. (5) in Step 4 is not satisfied, i.e., the LED panel cannot be detected, the UAV is moved in a predefined motion and iteration starts from Step 1. When the LED panel is detected, the following steps are continued to estimate the LED panel's position in input images based on constant green light noise.

- *Step 5:* Estimate blinking status function $b_s(i)$ from Eq. (6):

  $$b_s(i) = \cos\left(\frac{2\pi\cdot f_m\cdot t(i)}{T_p+\phi_m}\right). \quad \ldots\ldots \quad (6)$$

  This equation, which denotes a change in the number of green pixels under blinking frequency $f_m$, means that:

  if $b_s(i) \geq 0$, LED panel blinking is on.
  if $b_s(i) < 0$, LED panel blinking is off.
- *Step 6:* Obtain two accumulated images from a binary image $B_i(x,y)$ in Step 1-2.

  $$B_{on}(x,y) = \sum_j B_j(x,y) \text{ where } b_s(j) \geq 0 \quad (7)$$

  $$B_{off}(x,y) = \sum_j B_j(x,y) \text{ where } b_s(j) < 0 \quad (8)$$

  From these equations, $B_{on}(x,y)$ includes LED panel green pixels and other noise components like constant green light. $B_{off}(x,y)$ includes only noise components.
- *Step 7:* Estimate difference image $B_{diff}(x,y)$ from two accumulated images.

  $$B_{diff}(x,y) = \begin{cases} 0 & (B_{on}(x,y) - B_{off}(x,y) < 0) \\ B_{on}(x,y) - B_{off}(x,y) & (\text{other}) \end{cases} \quad (9)$$

- *Step 8:* Estimate the center of the LED panel $(x_g, y_g)$ by using $B_{diff}(x,y)$ as weight.

$$x_g = \frac{1}{w_s}\sum_{x,y} x \cdot B_{diff}(x,y) \quad \ldots\ldots \quad (10)$$

$$y_g = \frac{1}{w_s}\sum_{x,y} y \cdot B_{diff}(x,y) \quad \ldots\ldots \quad (11)$$

$$\text{where } w_s = \sum_{x,y} B_{diff}(x,y). \quad \ldots\ldots \quad (12)$$

If $(x_g, y_g)$ is not at the input image center, i.e., near the input image boundary, the UAV is moved so that $(x_g, y_g)$ is at the center of the image. The distance between the image center and $(x_g, y_g)$ is used as UAV movement gain. If $(x_g, y_g)$ is near the input image center, the pattern discrimination process is performed as detailed in the next section.

### 3.3. LED Panel Pattern Discrimination

In the sections that follow, we detail LED panel pattern discrimination, which is also described in [5]. In this paper, however, we modify the method because UAV and its on-board camera specifications are different, so we use only AR markers as patterns. We do not use QR and micro QR codes.

- *Step 1:* Using an input RGB color image taken by the UAV's on-board camera, convert input image color space from RGB to HSL and obtain a binary image of white pixels in the input image by using color parameters as was done in Step 1-2 in Section 3.2. This binary image will include the white frame of the LED panel.

- *Step 2:* The input image is taken under the vibration of the UAV hovering. To prevent the influence of motion blur in the input image, the Step 1 binary image is divided into the odd and even field images (**Fig. 4**). Using the ARToolKit software library [c] coordinates of outside corners in the white frames are estimated in each image. If corner points are estimated two or more areas in each image, we select points having the maximum area.

- *Step 3:* Using red pixels extracted by color parameters from the input image converted to HSL color space, we obtain a binary image in which red pixels are black and other pixels are white. We divide this binary image into the odd and even field images. LED panel areas detected from corner points in Step 2 in each field image are merged and rectified into rectangular image by projective transformation in which the size of rectangle image $D$ is predefined.

- *Step 4:* Prepare all AR marker pattern images whose size is enlarged to $D$ [pixels]. Moreover, we also prepare rotated pattern images (90°, 180° and 270°) for all patterns. Let $N$ be the number of AR marker patterns, so we prepare $4N$ pattern images.

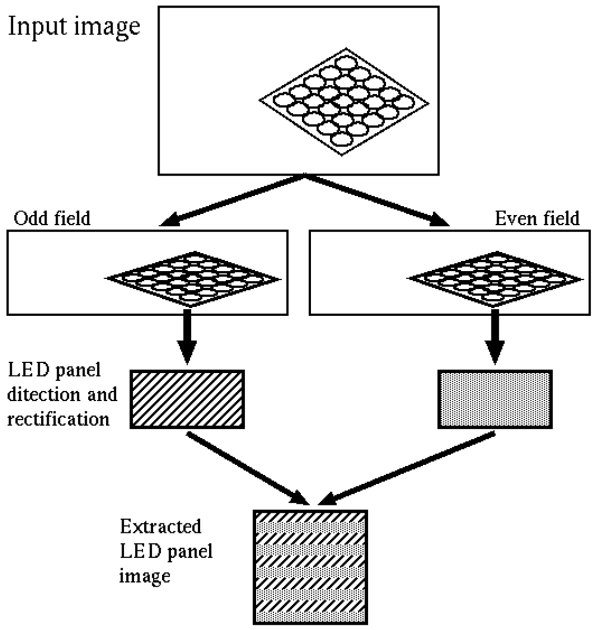



**Fig. 4.** LED panel area extracted using odd and even field images.

  Estimate the similarity of the rectified LED panel image in Step 3 compared to $4N$ pattern images. Similarity is calculated as the sum of the absolute difference of corresponding pixels [9].

  The LED panel pattern is discriminated to the AR marker pattern image when it has minimum similarity and its similarity is smaller than a threshold which determines valid discrimination.

  If this similarity is larger than this threshold, the LED panel pattern cannot be discriminated.

- *Step 5:* If the LED panel pattern is discriminated, the UAV perform a task related to this pattern.

## 4. Experiments

### 4.1. Experiments of LED Panel Detection

We show experiments of the LED panel detection in this and next sections. The experiments including pattern discrimination and UAV control are shown in Sections 4.3 and 4.4. We use the LED panel and UAV shown in Section 2. UAV flights in a laboratory room.

The LED panel we used flickers when blinking frequency $f_p$ becomes larger than 4 Hz. We think that this is because of dynamic lighting. When $f_p$ exceeds 4 Hz, any patterns can not be displayed stably on the LED panel. To display patterns stably, we set the blinking frequency of green frame $f_p$ to 2 Hz in the LED pattern. The AR markers, QR and micro QR code patterns displayed in red are changed every five seconds. The UAV (AR.Drone) takes images at about 60 frames per seconds. We set the number of images $N_p$ to be detected at 128, so the processing

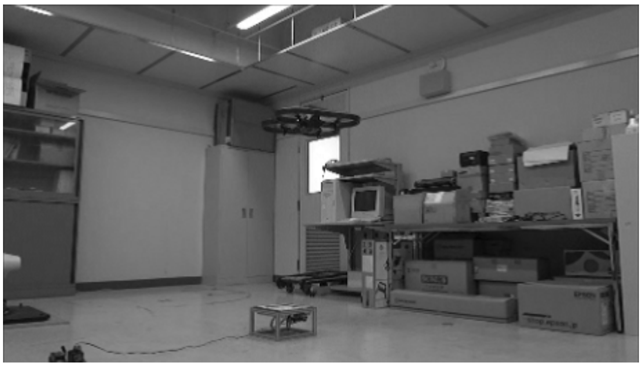
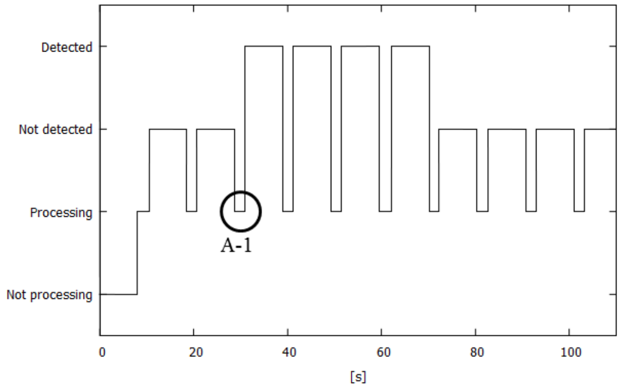
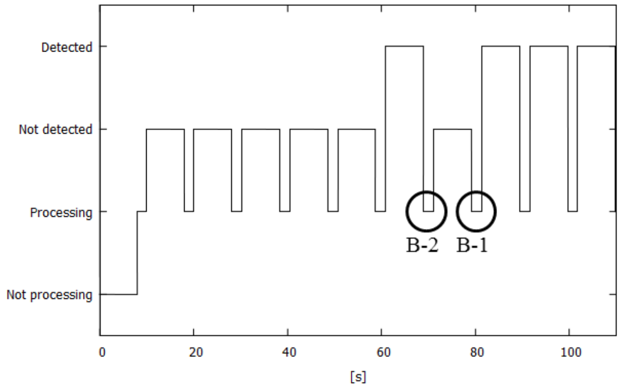


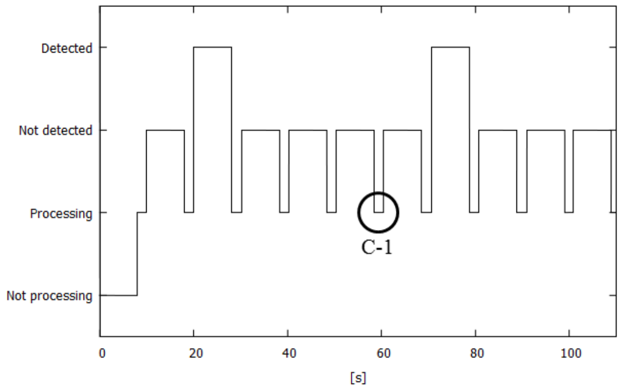
**Fig. 5.** LED panel detection experiment.




(a) Case of Type-A.




(b) Case of Type-B.




(c) Case of Type-C.

**Fig. 6.** LED panel detection results.

time for 128-image capture $T_p$ is about 2 seconds. Images are captured while the UAV is hovering.

In this experiment, we consider the noise versus the the LED panel blinking pattern. We compare the following three types of patterns:

- *Type-A:* Only a LED panel is used.
- *Type-B:* For constant green light as noise, the LED panel always displaying a green square pattern is arranged near the target LED panel.
- *Type-C:* For random green light as noise, the LED panel intermittently displaying a green square pattern is arranged near the target LED panel. Intervals when light is on and off in the green square pattern are changed randomly from 0.1 to 1.0 seconds.

In experiments, we performed the following steps in the panel detection experiment:

1. After takeoff, the UAV is moved manually to where it is above the LED panel for eight seconds.
2. For about two seconds, the UAV hovers automatically. In this time, images are captured and panel detection process is performed. But the UAV has small movements because the UAV receives wind caused by itself in the experiment in the room.
3. After presenting panel detection results, the UAV is moved manually for eight seconds to adjust its position and altitude appropriately.
4. Iterate the above steps 10 times, completing this experiment.

## 4.2. LED Panel Detection Results

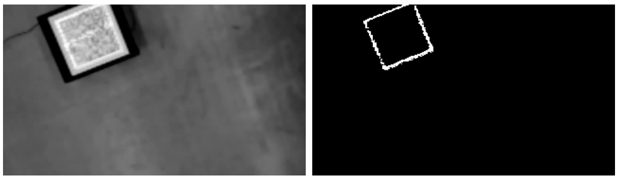
**Figure 5** shows a scene of the LED panel detection experiment. **Fig. 6** sequentially shows the results detected for types A, B and C. The horizontal axis denotes the time (s), with 0 as the takeoff time. The vertical axis denotes status as follows:

- Not processing: manual handling of the UAV.
- Processing: image capture and panel detection process.
- Not detected, Detected: detection results.

The intervals of “Not detected” and “Detected” denote manual handling time for eight seconds.

**Figure 7** shows input and binary images of green pixels in A-1 and B-1 as denoted by black circles in **Figs. 6(a)** and **(b)**. **Fig. 8** shows green pixel distributions and estimated blinking frequency $f$ in A-1, B-1, B-2 and C-1 in **Figs. 6(a)**, **(b)** and **(c)**.

In the type-A experiment, the LED panel is detected four times in 10 processings. The LED panel is not de-



(a) Case of A-1.

(b) Case of B-1.

**Fig. 7.** Input (left) and extracted green pattern (right) images.

tected six times because the LED panel does not always appear in the input image sequence because the UAV is not still in same place while hovering. As shown in **Fig. 8(a)**, however, in which the LED panel gradually disappears in the input image sequence, the LED panel is detected by using the proposed method even if part of the LED panel appears in input images.

In the type-B experiment, the panel is detected four times as happened above. Here, green pixel distribution includes a bias component because of the constant green light. Even in such a situation, the LED panel is detected as shown in **Fig. 8(b)**. Because the UAV moves slightly while hovering, however, this bias component might be changed as shown in **Fig. 8(c)**, so blinking frequency cannot be estimated correctly from the maximum power spectrum.

In the type-C experiment, the panel is detected only twice. Because of random blinking, the LED panel blinking frequency cannot be estimated as shown in **Fig. 8(d)**.

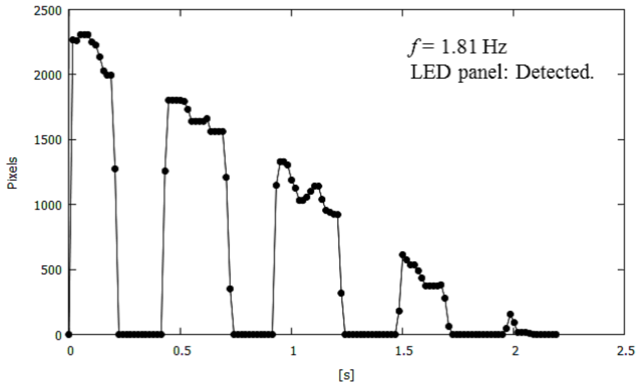
As our results show, the LED panel is detected by our proposed method even if the constant green light exists as noise. But, it is difficult to detect the LED panel under random blinking green light, and the UAV moves slightly as it captures the input image sequence. To make detection more accurate, we must consider the UAV hovering control and short image sequence acquisition.

When blinking frequency $f_p$ is set to 4 Hz, we can get almost same results in above experiments. When $f_p$ is set to a large frequency, image capture time becomes short, so we set $f_p$ to 4 Hz in experiments in Section 4.3.

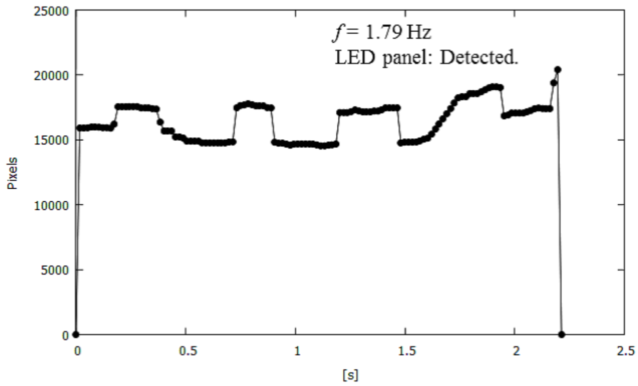
### 4.3. UAV Flight Control Experiments

To show experimental results of UAV (AR.Drone) flight control by the LED panel, we prepare six AR markers as LED panel settings, as shown in **Fig. 9**. These markers are related to the following tasks:

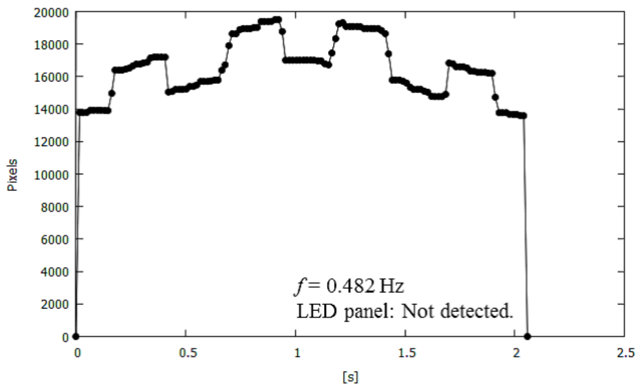
1. (H) Hovering in place.
2. (R) Rotate slightly right.
3. (L) Rotate slightly left.



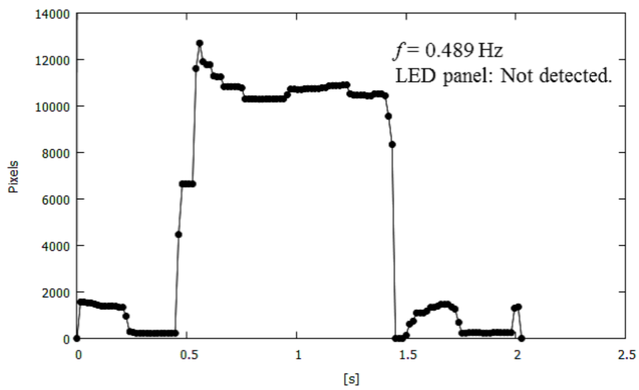

(a) Case of A-1.




(b) Case of B-1.

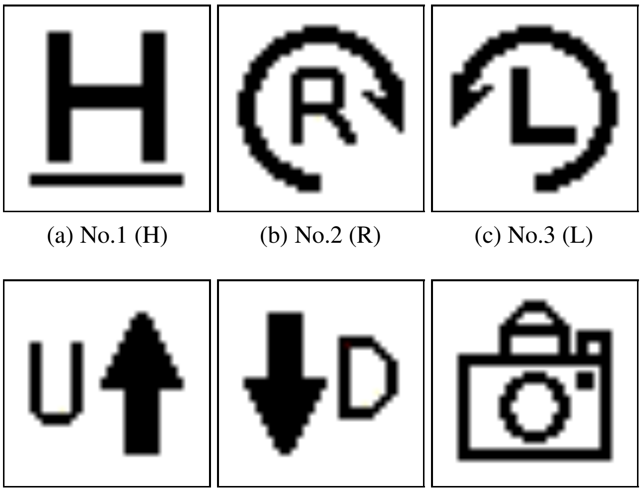



(c) Case of B-2.




(d) Case of C-1.

**Fig. 8.** Extracted green pixel distribution and estimated blinking frequency.




(a) No.1 (H) (b) No.2 (R) (c) No.3 (L)

(d) No.4 (U) (e) No.5 (D) (f) No.6 (C)

**Fig. 9.** AR markers.

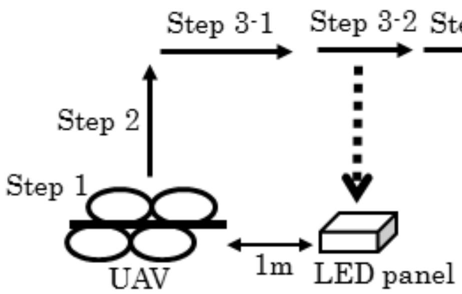



**Fig. 10.** UAV operations in experiments.

4. (U) Elevate (up) slightly.

5. (D) Descent (down) slightly.

6. (C) Take a photograph using the front camera.

(H), (R), (L), (U), (D) and (C) in the above tasks are names of AR markers, and "slightly" means that the UAV performs the indicated movement for one or two seconds.

The green frame blinking frequency is $f_p = 4$ Hz in the LED pattern. Six AR markers are displayed in red and changed sequentially every five seconds. From results given in Section 4.2, the number of images $N_p$ for detection is set to 64, so image capture processing time $T_p$ is about 1 second – shorter than experiment in Section 4.1.

In the experiment that follows, we perform the following steps (**Fig. 10**):

- *Step 1:* The LED panel is located in front of the UAV about 1 m away from it.
- *Step 2:* After the UAV taked off, its altitude is adjusted manually from 1.5 to 2.0 m for about 8 seconds.
- *Step 3:* The UAV mode is changed to autoflight.
  - *Step 3-1:* If the UAV cannot detect the LED panel (Step 2-a in Section 3.1), it moves forward slightly because the LED panel is assumed located in front of the UAV.
  - *Step 3-2:* If the UAV detects the LED panel (Step 2-b in Section 3.1), it detects the LED panel and determines the pattern.
- *Step 4:* When the operator clearly judges that the UAV can no longer detect the LED panel, the UAV is manually landed.

We iterate the above steps five times. Note that, in Step 3, when the UAV does not need to be moved, we have it simply hover.

### 4.4. UAV Flight Control Results

**Figure 11** shows some of the results of the UAV flight control experiment. The dotted line in the lowest graph denotes the AR marker name displayed on the LED panel. The solid line in the middle graph denotes UAV status. The horizontal axis denotes the time (s). 0 is the takeoff time. The vertical axis denotes AR marker name and UAV status. The thin line in upper side of graph denotes UAV altitude measured by UAV's ultrasonic sensor. The altitude value has a large error, but relative altitude changes appeared. In this graph,

1. The UAV changes to autoflight control mode at 9 s after takeoff.

2. The UAV performs the panel detection process, but the LED panel cannot be detected for three times.

3. In fourth detection process, the LED panel is detected and the UAV performs the pattern discrimination process. This discrimination is success and discriminates the LED panel pattern as pattern (R), then performs the related task of rotating slightly to the right.

4. In fifth panel detection process, the UAV detects the LED panel. But, the LED panel position in the input image is not centered, so the UAV is moved to "forward."

The UAV then iterates panel detection and pattern discrimination. Based on the AR marker displayed on the LED panel, especially, elevate (**Fig. 9(d)**) and descent (**Fig. 9(e)**), the UAV's altitude is changed, but there is some delay because commands from the PC to the UAV are sent by the TCP/IP communication via Wi-Fi.

**Table 1** summarizes of the UAV flight control experiment, and shows the number of panel detections and pattern recognitions. No.1 is the case for **Fig. 11**. From **Table 1**, we found the following two rates:

- Total LED panel detection rate $(b/(a+b))$: 67.2%
- Total AR marker discrimination rate $(d/c)$: 75.0%

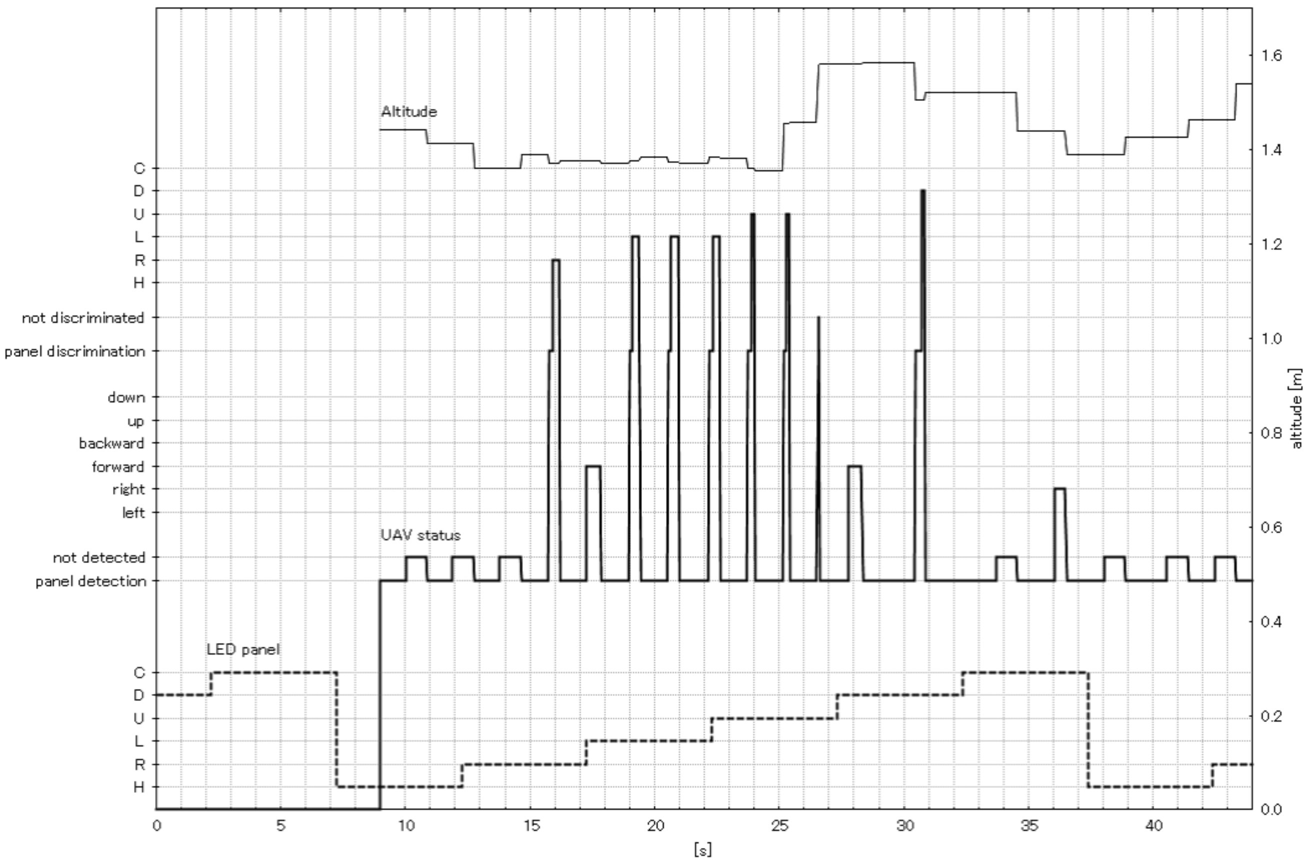



**Fig. 11.** UAV flight control results.

**Table 1.** Panel detection and pattern discrimination results.

| No. | Auto flight time [s] | Num. of detection | No panels in images | Detection | | Num. of | | Discrimination | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Failure | Success | Moving | Discrimination | Success | Failure |
| 1 | 34.3 | 18 | 4 | 3 | 11 | 3 | 8 | 7 | 1 |
| 2 | 36.4 | 15 | 3 | 7 | 5 | 0 | 5 | 5 | 0 |
| 3 | 28.5 | 14 | 4 | 5 | 5 | 1 | 4 | 4 | 0 |
| 4 | 26.8 | 13 | 3 | 4 | 6 | 3 | 3 | 2 | 1 |
| 5 | 41.6 | 24 | 3 | 3 | 18 | 6 | 12 | 6 | 6 |
| | Total | 84 | 17 | 22<br>(a) | 45<br>(b) | 13 | 32<br>(c) | 24<br>(d) | 8 |

We can therefore show that our proposed method controls the UAV automatically.

The panel failed to be detected for the following reasons:

- The LED panel does not always appear in the input image sequence even for 1 second during hovering.
- Wi-Fi communication breaks off and images are not input to the PC correctly.

These reasons suggest that we must discuss stable hovering and on-board microcomputer processing for our proposed method better.

Pattern discrimination failed for a number of reasons. These include fact that the LED panel appears very small in the input image. This experiment was done indoors, so the relationship between pattern discrimination accuracy and UAV altitude could not be investigated because the indoor ceiling was low. We thus plan to investigate this relationship in future work.

Even though the LED panel appears small, it is detected by the blinking pattern, so we should use a video camera to control focus and zoom. We must also discuss ways of adjusting focus and zoom automatically and appropriately based on the panel detection and pattern discrimination processes.

## 5. Conclusions

Having discussed UAV flight control using LED panels and a video camera on the UAV, we proposed LED panel detection using a blinking pattern and reviewed flight control experiments. We confirmed that our proposed method controls the UAV as desired by using the LED panel.

To apply our proposed method to outdoor flight, we must be able to capture LED panel images stably. To detect the LED panel, the UAV's on-board camera should take images over a wide range. To realize these functions, we could attach gimbals to the UAV. Attaching the on-board camera to gimbals would suppresses the influence of UAV vibrations in image capture. We could also enlarge the photography range by using gimbals as a high flexible camera platform.

In future work, we plan to discuss panel detection and pattern discrimination methods that are more accurate and faster. We would also like to confirm the effectiveness of our proposal in outdoor settings.

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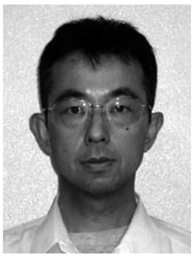

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