Flying Display: A Movable Display Pairing Projector and Screen in the Air

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Abstract

We developed Flying Display, a novel movable public display system which can provide information to the people anywhere at anytime. This system consists of two UAVs (Unmanned Aerial Vehicles) with a projector and a screen. Flying Display achieves moving freely and keeping stable in 3-D space. Flying Display moves closer to people and gives information directly to them. To evaluate performance of Flying Display, we performed two experiments for adapting a flying control algorithm. We also showed the stability of Flying Display systems by trajectories of each UAV. This paper highlights the performance of Flying Display and discusses the Flying Display's potential for public displays in physical space.

Author Keywords

Flying Display; Movable Public Display; UAV; Mobile Contents; Social Robot;

ACM Classification Keywords

H.5.1 [INFORMATION INTERFACES AND PRESENTATION]: Multimedia Information Systems.

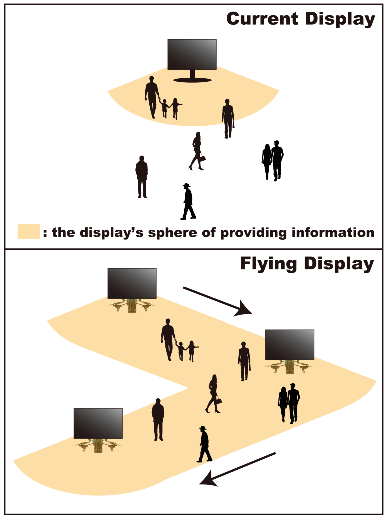


Figure 1. Through using Flying Display, people get a new opportunity to get some contents.

Introduction

More and more people are involved in activities on the Internet. They are accustomed to be exposed to a huge amount of information over the years. Because of its scale size and interactivity, various ways of delivering information to public has been involved and developed. For example, displays are placed at various public spaces such as shopping malls and stations, providing local information including maps and news directly to neighboring people [2, 7]. This type of technology called public display has become much more effective and useful in using space and delivering the latest information to the public. However, these displays are commonly implemented on walls, floors, or ceiling with limited mobility. Therefore, they sometimes fail to deliver information to people when contents on display are not seen when even some people potentially have interests in the information.

In this paper, we propose Flying Display, a new model of public display. Flying Display can move freely and quickly in 3-D space, and keep stable above one spot. This display moves closer to pedestrians and gives information directly to those people (Figure 1). Therefore, we can overcome current public display's problem some people missing information when they are moving and paying little attention to public displays. In addition, Flying Display always rotate with paired a screen and projector with function to control flying parameters. Flying Display can also change its screen's surface on each and every angle of people's eye levels (Figure 2). Flying Display must be used at any place at any time, in which spaces allocated inside or outside buildings.

To achieve a new model, the requirements for Flying Display are continuity, maintenance and safety. As the first step, we focus on the aspect of continuity in this paper. We use Unmanned Aerial Vehicles (UAV) to control the display to fly anywhere. We use off-the-shelf UAV operable by programming. The direct approach for Flying Display is just mounting LCD display on UAV, however, current display is heavy to be carried by UAVs. In our research, we separated the function of display into a projector and a screen to keep the devices' weight under the limit and yet succeeded in providing a feature of the display implementing it at a larger size. Flying Display consists of a drone with a projector (called "projector-drone") and a drone with a screen (called "screen-drone"). During its flight, the body movement is stabilized, using our algorithms and computer vision technique. The key contributions of this paper are the followings:

- We propose Flying Display as a new model for public display in urban environment.
- We present a prototype and performance that coordinate devices with UAV.
- We evaluated the accuracy and stability of Flying Display system using prototype and showed future work.

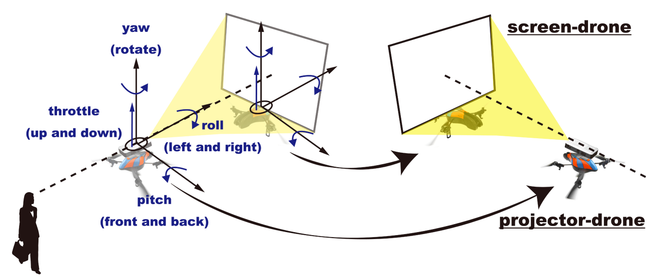


Figure 2. Flying Display controls its screen's surface at right angles to people's eye level in 3-D physical space.

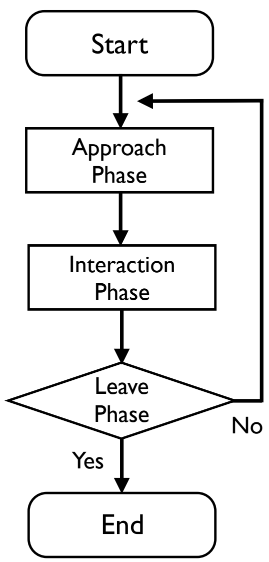


Figure 3. Flying Display's Interaction Flow

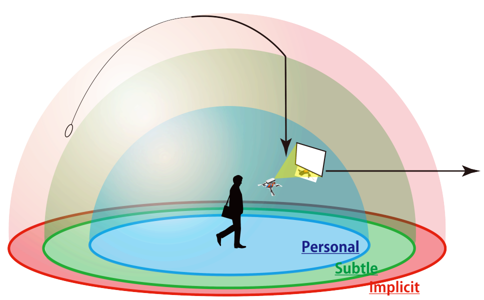


Figure 4. Our interaction model focuses on how the display approaches people, with supporting three zones of interaction for distance dependent.

Related Work

In the field of robotics, some robots that actively moves closer to people already exist. Human interaction anticipation is used to provide information for more specific and targeted users. Kanda et al. [3] analyzed human behavior using cluster approach to make anticipation profiles. Shops and stores can deliver their services through their robots for those who are more likely to purchase their products. However, these robots can only move over the planar ground, so they are not suitable for the situation in a crowd people.

Mobile contents research is on argumentation of static surface with digital information using mobile devices [6]. Jurgen et al. [5] introduces Displaydrone that combines a multicopter (flying robot) with a pico-projector and mobile phone. Displaydrone can project onto walls and flat objects in physical space. However, Displaydrone is capable of only projecting onto a fixed surface, such as walls and the ground. People have limitations of their eyesight angles incapable of changing projection surface's angle. All these systems explained here relies on whether there is a static surface in physical space.

Interaction Flow

In the field of interactive public displays, there have been many interaction frameworks about audience behavior that is readily observable. For example, Muller et al. [7] categorized interaction with public displays' in several phases by an outside observer in front of anchored display on the wall. However, in case of Flying Display the interaction model should be different because the interaction depends on not only the movement of people but also the movement of people.

We showed our interaction flow in Figure 3. Our key focus is the converse interaction model to determine where Flying Display should move to and how it should approach passer-by. Our key feature is how Flying Display approaches from out of visual field, since it is crucial to grab the attention of passer-by.

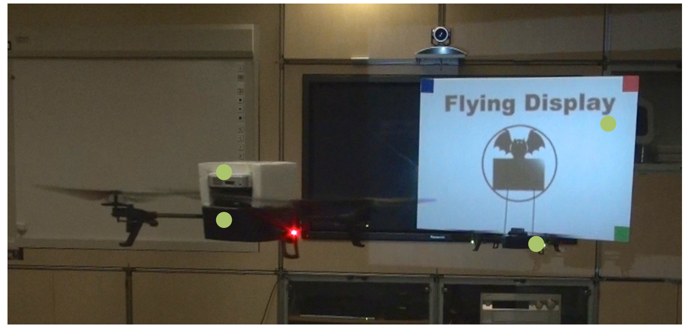
We present our interaction model in Figure 4. We modified Vogel's interaction model [2] focused the range from the display to the model focused range from the people. Our interaction model covers the range from distant, with three categories in distant order from people; Implicit Interaction, Subtle Interaction, Personal Interaction. These categories are arranged around the passer-by on the concentric circle relied on physical proximity. Then, we defined three phases; approach, interaction, leave in Figure 3. In the approach phase, when Flying Display is approaching to people, it depends on four parameters; sensing context like that such as the target user, destinating position, approaching path and approaching movement. After Flying Display comes into the surroundings of passer-by, we can apply previous static public display interaction in the interaction phase. Finally, in the leave phase, Flying Display can change its position in minimum of distance to leave the range of interaction around passer-by. By choosing one from each phase in Table 1, Flying Display framework is determined uniquely.

Approach	Interaction	Leave
Context	Modality	Position
Position	Contents	
Path		
Movement		

Table 1. We defined three phases included some parameters.

A mobile projector in use is epico with device size of 125 x 65 x 25mm (W x D x H) and a weight of 150 grams. It has 50 ANSI lumen light power.

projector-drone: a drone with a projector. This follows the path screen-drone through head camera by computer vision technique.



We use a white board as screen equipped UAV. Screen's size is 760 x 540cm (W x H). Visual marker is put on screen.

screen-drone: a drone with a projector. This is master in master-slave relationship.

Figure 5. Flying Display as a first prototype

Flying Display

Research Challenges

Research that challenges of the continuity for Flying Display are the followings, (1) how to develop a stabilized flying projector and screen (2) how to control each UAV to be in coordination with one another.

Hardware

Flying Display System is realized with UAV that can move freely and keep its positional state at any point in physical space. We created a prototype with state-of-the-art Parrot AR Drone 2.0 [1]. We have pre-experimented whether the flight with a screen and a projector is possible for the drone. The suitable screen and projector was chosen for the prototype drone. It has a carrying limit of about 200 grams. For the projector, we considered the carrying limit of the drone and the amount of lumen, and then selected epico from TOP-ONE Co. Ltd. For the screen we have chosen the most light and strong white board. Both the projector and screen were set on the top of the drone to minimize the effect of the wind made by the drone itself. Also, placing the two was done carefully, to balance them well on the drone. As a result, we have confirmed that it was possible for the drone to fly with a projector or also a screen.

Software

To discover the stability during each flight, we implemented real-time flight coordination system based on feedback such as yaw, pitch, and roll angles from sensors on drones. Moreover, two drones are in master-slave relationship, projector-drone always follows the path that screen-drone has passed. Projector-drone detects a visual marker on screen-drone to calculate relative location and distance to the screen-drone. Then, projector-drone follows screen-drone's path and keep a constant distance between the two drones. In addition, these two drones are connected to a wireless network, on which sensor information is exchanged in real time. A master computer reads the shared parameters and the wireless network and calculates their states. Furthermore, the master computer simultaneously adjusts flying heights and angles of the drones on the same level to one another. A first prototype (Figure 5) is implemented based on the AR Drone Open API.

Evaluation

We conducted two experiments to evaluate that Flying Display could keep the display stable while hovering and moving to the side.

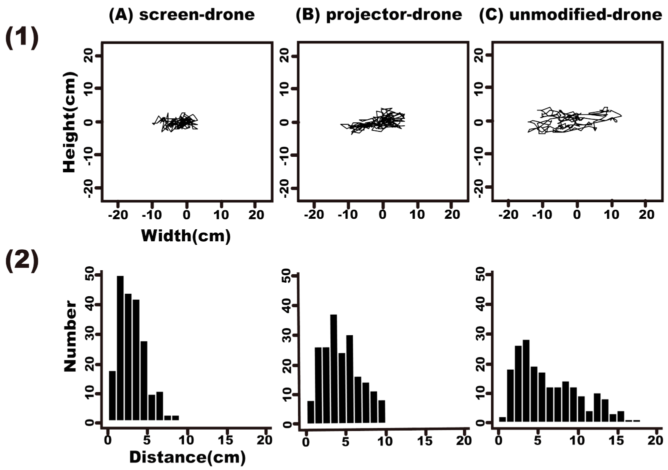


Figure 6. (**1**) We obtained each drone could keep within the limits of 40cm from their trajectories. (2) We calculated the distance between the central point and hovering point 200 times.

Stable Hovering

In this experiment, we evaluate the stability of our flying system when a drone is hovering above one spot. Our system is based on parameters from sensors on a drone to adjust its flight angle for stabilization. We evaluated the stability of (A) a drone with a screen implemented and (B) a drone with a projector equipped. We used (C) an unmodified drone as a controller. (A) and (B) are both adjusted using our flight stability system, and (C) is controlled by its stand-alone adjustment. We performed this experiment for 100 seconds each hovering captured by camera and scaled position at every 2 fps (as shown in Figure 6 (1)). For each hovering, we detected the central point among hovering louses, and calculated the distance between the central point and each hovering point (as shown in Figure 6(2)). We confirmed that flying stabilities of both A and B were significantly higher than C (p < 0.05; Wilcoxon Rank test). This result indicates that our flight system achieves higher stability performance than a drone system. Therefore, we found that our system culd provide a stable display while hovering.

Flying Control Technique

We have conducted an evaluation where we compared the projection accuracy when using/not using a visual marker. The evaluation took place on horizontal and flat ground. The setup of this experiment is the following; we walking back and forth with two turns between two points (five meters – total in 15 meters) in each line taking 20 seconds with a screen with 9 dots placed in a grid. Dots are to be covered in light coming from a projector placed on a drone. We did the walking two times; (A) once with a drone visual marker tracking ability activated and another time (B) with a drone stand-alone moving ability activated. We recorded and rendered this experiment video clip in 4fps and counted the dots that are covered in light from a projector. The highest accuracy in this experiment was 20 seconds * 4 fps * 9 dots = 720 dots covered in overall (as shown in Figure 7). In the case of (A), 528 dots (73%) were covered in light and in the other case (B) only 393 dots (54%) were covered in light. As a result, the flight accuracy of (A) is significantly higher than (B) (p < 0.05; Fisher's exact test). Therefore, we concluded that the case with visual marker is significantly higher in accuracy of tracking than the case of stand-alone moving.

Discussion

Advertisement

Flying Display has a potential to be a new type of advertisement device. Displays in public place have a downside that it is hard to catch the pedestrians' attention. On the other hand, Flying Display can fly to the target and catch ones attention firmly. We have demonstrated Flying display in a big hall at Open Research Forum 2013 in Tokyo Midtown and succeeded to grab the participants' attention. Many people stopped and glanced at the drone and people from far away also came when they found the flying display. To sum up, Flying Display has the potential to be a new type of advertisement to give people opportunities to discover new things and information.

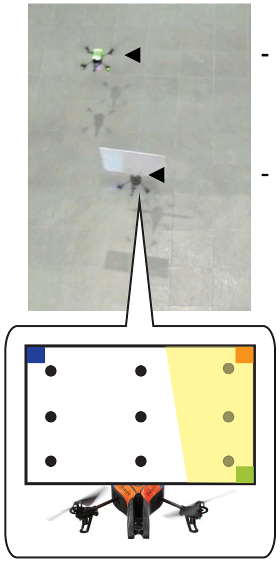


Figure 7. There are three dots covered in light for example.

Maintenance

Since UAVs run with battery, they can fly only for short time. For example, the battery life of drone with live video streaming lasts only for 30 minutes, so drone has to land multiple times in order to charge its battery. A way to overcome this problem is to convert drone operated with power-supply cables. We connected drone to DC power supply on the ground, so each projector-drone and screen-drone can fly without battery for a long time [4]. It is possible to use both drone with battery and without battery for various situations.

Safety

There is a weak point of that Flying Display in that it can be extended to a larger scale combined with other displays depending on the surrounding environment. In the next stage, we will ensure higher the safety and safety of interacting users in how a drone is approaching to public.

Conclusion

In this paper, we have presented a new public displaying system; Flying Display, which can move freely and display information in any space. To realize large display equipped UAV, we separated the function of the display to a projector and a screen. Using two UAVs mounting a projector and screen, we have shown the stability of the flying system with a projector and a screen. To find the stability during both projector-drone and screen-drone flight, we implemented flight coordination system based on a visual marker tracking using a color tracking scheme and adjusting flying heights and angles of the drones on the same level to one another. From the trajectories result, we obtained that a flying projector and screen could be controlled for stabilization. In addition, we showed that accuracy of visual marker tracking (73%) was more effective in the accuracy of stand-alone moving (53%) with our flying control. Lastly, we demonstrated that Flying Display has a potential to be a new and creative model for public display.

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