

The Model of the Drone System Design for a Multi-recording of the 360-degree Video and Real-time Merging Technique

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Abstract Background/Objectives: Various attempts have been made to utilize drones to increase information utilization based on the 4th industrial revolution. As the availability of these drone increases, the demand for real time image information at various angles is increasing. So we need to make a research like it. **Methods/Statistical analysis:** We propose a drone design model for 360-degree simultaneous multi-recording videos and a real-time video merging technique to provide efficient real-time video service in order to reduce blind spots that can occur in drone adjustment and to provide surveillance efficiency. In order to collect videos at various angles at the same time by using multiple cameras, we analyze the angle of the camera with respect to the split plane of the drones, and provide real-time video information service through efficient 360-degree videos construction and videos merging. It can be make an effective coordination and monitoring of a drone. **Findings:** The drones typically include one or two cameras for situational and video recording purposes, but this camera approach creates a blind spot in drone surveillance area. And also VR and 3D approach with first-person equipment of drone is lacking the real-time monitoring function at various angles in that it provides only one viewpoint at a time. In addition, it is required to recognize and utilize information more efficiently in the reality that the drones are being extended from the visibility flight to the non-visibility area. The simultaneous 360-degree video recording method using multiple cameras will improve the monitoring and operation ability of the drones and increase the utilization. To do this, we analyze multiple camera angles and construct the physical environment of the drone system for the collection and processing of effective video information. We also propose a video merging technique to provide efficient service of collected video information. **Improvements/Applications:** Based on the relation between various elements constituting the drone, it can be used in various application

environments by providing an efficient access and communication environment for monitoring and information required in the operation of the drone through the camera environment, real-time information collection and merging technique.

Keywords UAV, Drone, Multi-recording, 360-video, Video Merging, Real-time Service

1. Introduction

The demand and utilization based on the drones are demanded through the increase of information gathering and utilization mainly with the 4th industrial revolution, and various studies for this purpose are being rapidly expanded worldwide [1,2]. SESAR's study suggests that by 2035, there is potential for in excess of 400 000 drones with the majority flying beyond visual line of sight and many, including for delivery purposes, being demanded for in populated settings at these very low levels of airspace [3,13]. And also the utilization field will expand to various fields such as agricultural disaster prevention and facility inspection [4,5]. Also, various applications and service environments of the drone field are being expanded through the upgrading of the image processing and sensor utilization technology linked with IoT [6,7,8]. Recently, the Ministry of Land, Infrastructure and Transport has selected eight areas of business using drones as transportation, coastal monitoring, forest protection, communication network, safety diagnosis, agricultural support in Korea. Various activities are being carried out for the necessary projects [9,14]. The increase in demand for these drones requires diverse systems that can operate the drones operating service environment more securely and efficiently. In order to do this, it is necessary to

construct a low-altitude UAV traffic management system (UTM), and at the same time, an efficient method of operating the drone in various viewpoints including the non-visible region is required [10, 15]. In this paper, we propose a drone system design model for real-time 360-degree simultaneous multi-video recording and a merging technique of the 360-degree videos to provide efficient real-time acquisition of collected videos to provide efficiency of drone adjustment and monitoring. To do this, we analyze the relationship between the multi-camera and the drone splitting plane necessary for 360-degree real-time image information collection, propose an efficient camera utilization approach, and suggest real-time image information collection and merging techniques to provide an effective monitoring and operating environment. This approach can be applied to various applications of drones by effectively providing more precise drone manipulation and monitoring functions. The composition of the paper is as follows. In Chapter 2, we discuss the relationship between the drones and the camera structure and the design method for securing the 360-degree simultaneous multi-video recording. In Chapter 3, we deal with the 360-degree videos merging technology for providing efficient simultaneous

multi-videos. Section 4 presents the drone system design model that provides 360-degree simultaneous 360-degree video service based on the data analyzed in Chapters 2 and 3. Finally, Chapter 5 discusses the conclusion and future challenges.

2. Relationship between Drones and Camera Structure for Real-time 360-degree Simultaneous Multi-video Recording

The drones can capture various angles in the air, and the camera constructs images with horizontal and vertical angle of view. In the drones, the camera must be placed on the outer surface of the drone to obtain an effective image, and the area covered by the angle of view is determined. There is a need to analyze the effects of camera angle on source credibility and attraction on camera utilization and accessibility and relationships of camera angle. These studies are also diverse [11, 12, 16]. We then analyze the relationship between the camera and the drones in the form of Figure 1 to form 360-degree simultaneous angles in the drones.

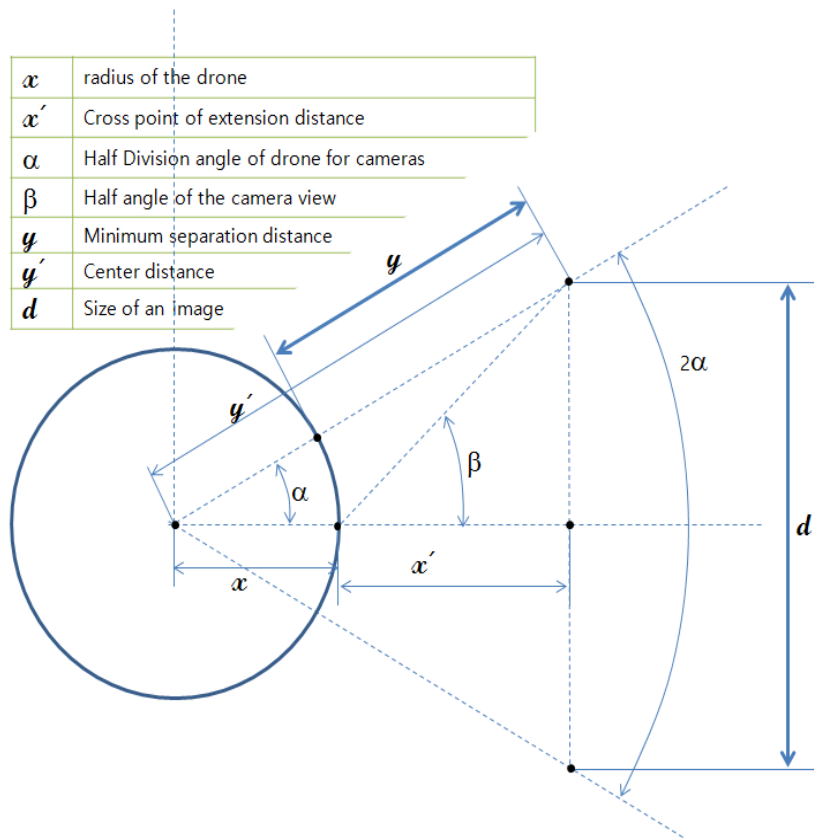


Figure 1. Video image size relationship of the drone's camera angle of view

Includes the camera installed in the drone is determined by the number of drones divided, the angle of view of the camera, and the radius of the drone to determine the distance and the number of cameras that can capture the entire 360-degree image. As shown in Fig. 1, when the radius of the drone is x when the camera is divided into the angle α , it is possible to obtain the minimum distance y value that can obtain the entire image by the angle of view β of the camera. You can determine the video size d and the number of cameras.

2.1. Minimum Distance for Securing a 360-degree Image according of a Drone

In relation to the camera angle of the unmanned aerial vehicle and the video image size, we can analyze the minimum separation distance for 360-degree image acquisition. We can summarize the relationship between

them as Eq. (1).

$$(x + x') \times \tan(\alpha) = x' \times \tan(\beta), \quad x' = x \times \frac{\tan(\alpha)}{\tan(\beta) - \tan(\alpha)}$$

$$y' = \frac{(x+x')}{\cos(\alpha)}, \quad y = y' - x \tag{1}$$

$$c = \frac{\pi}{\alpha}, \quad d = ((x + x') \times \sin(\alpha)) \times 2$$

Equation 1 shows the relationship between the minimum separation distance and the image size according to the drone split plane and angle of camera. Through this, it is possible to analyze the minimum distance, number of cameras, and image size for securing the simultaneous 360-degree simultaneous image according to the angle of view of the circular drones and the angle of the camera used. Figure 2 shows the minimum separation distance according to the division plane and angle of view for securing a 360-degree image.

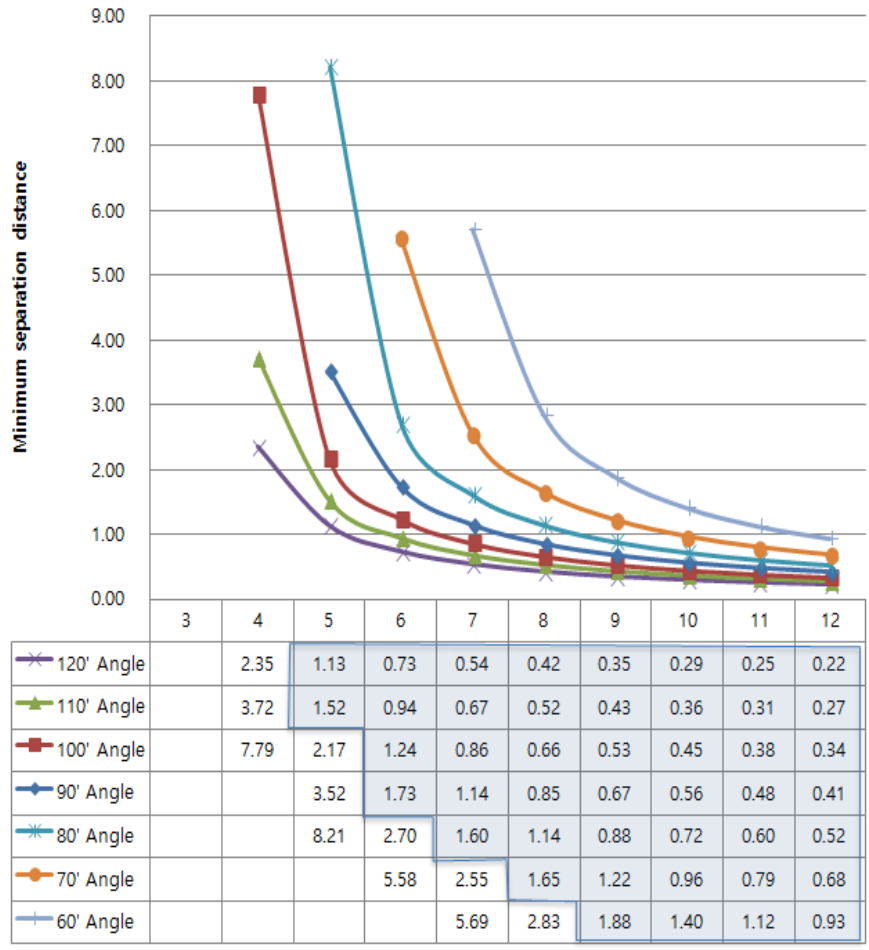


Figure 2. Minimum distance for securing a 360-degree image according to circular drones divided plane and angle of view of camera

In the relation between the computed angle of view and the division plane, six cameras are required to create a minimum separation distance of 1.73 when the vertical angle of view is 90 degrees with respect to the half angle of the drone 1. Also, the corresponding minimum horizontal angle of view is required to be five cameras at over 110 degrees.

2.2. The Minimum Number of Cameras through Vertical and Horizontal Division for a Drone to Get a 360-degree Video

In addition, the minimum number of cameras through vertical and horizontal division for 360-degree drones can be derived as shown in Equation 2 below. At this time, the

number of side partitions is even division by the condition that the up and down camera is provided.

$$t(x,y) = y + (y - 2) \times \left(\frac{x}{2} - 1\right), t(x,y) = \left(\frac{y}{2} - 1\right)x + 2 \quad (2)$$

Using Equation 2, we can analyze the minimum number of cameras for 360-degree images in a drone. Based on this equation 2, we can obtain the relationship between the minimum camera number of the drones according to the plane and side splits as shown in Figure 3.

x represents the number to divide by **x-axis** and **y** represents the number to divide by **y-axis**. Figure 3 below shows the number of cameras along the **x, y** axis. As shown in Fig. 3, the number of cameras is required 14 cameras to divide the **x-axis** into six sections.

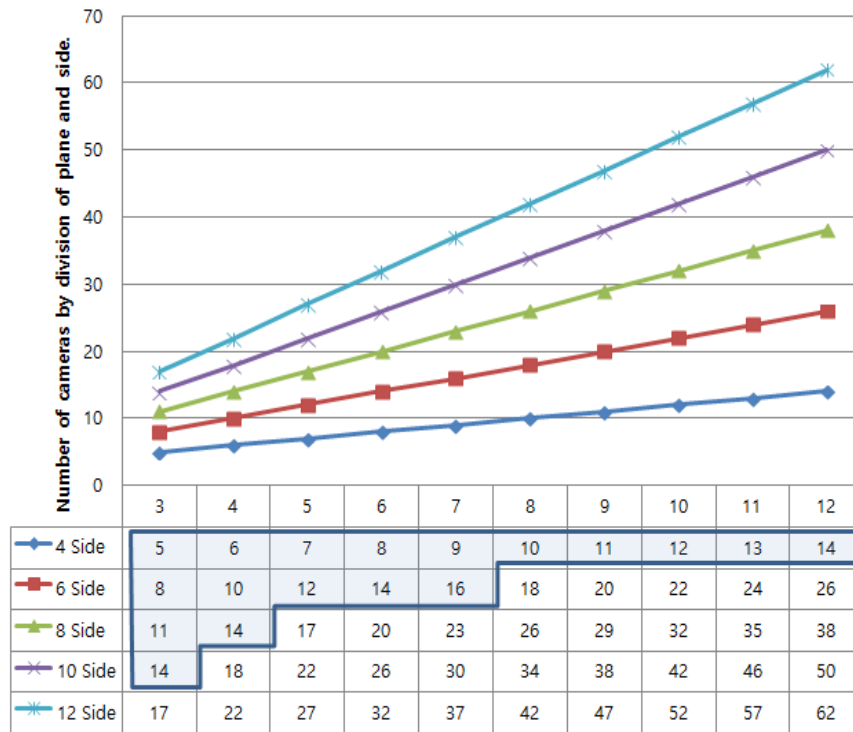


Figure 3. Minimum number of cameras of a drone based on division of plane and sides

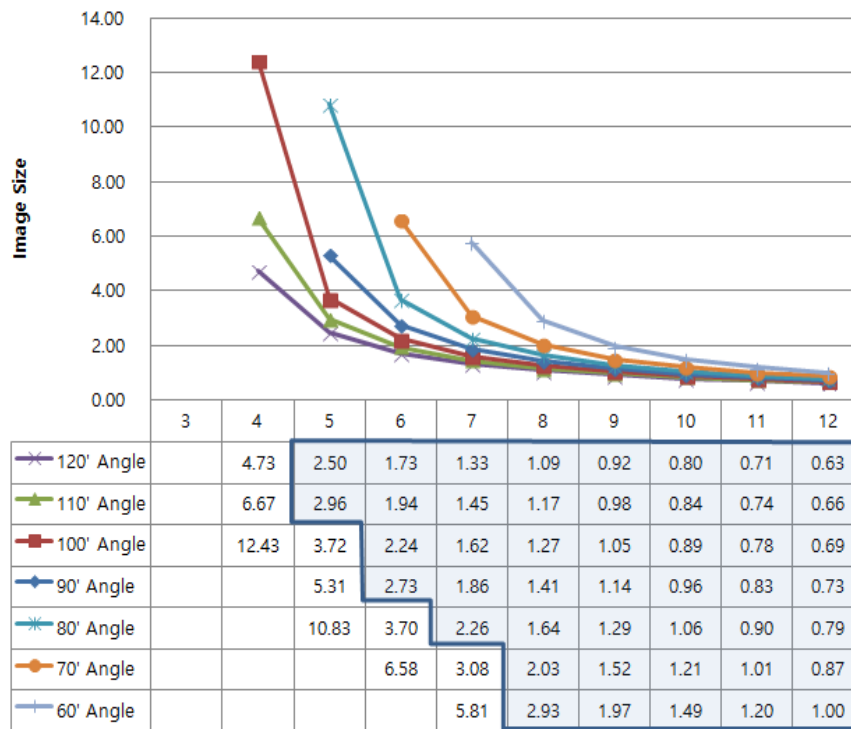


Figure 4. Relation of image size and a drone according to angle of view and division plane

2.3. Image Size according to Angle of View and Division Plane

The size of the image can be determined according to the size of drone, the angle of camera view, and the division plane of the drones. The relationship between the size of the drone of radius 1 and the image size is shown in Figure 4.

The size of the image can be determined according to the size of drone, the angle of camera view, and the division plane of the drones. The relationship between the size of the drone of radius 1 and the image size is shown in Figure 4. When 360-degree simultaneous multi-images are acquired through the angle of view and divided surface, the collected images should be efficiently transmitted to the ground control system through appropriate processing procedures. The provision of all collected images increases network traffic and makes real-time image service difficult. The collected images need to be provided to the ground control system through an optimized merging process before being provided to the ground control system. Section 3 shows the process of merging these images.

3. Merge Method for 360-degree Simultaneous Multi-images

Based on the analyzed angle of view information for the drone, this paper proposes a 6x6 split 360-degree simultaneous multi-video recording drone design structure and analyzes the multi-image merge technique required. The image merging is based on the information obtained from 14 cameras, and the 360-degree merged image can be obtained by merging the images. To obtain various image merging points for the vertical and horizontal angle of view, the relationship of the elements shows in Figure 5.

As shown in Figure 5, we can extract the merged points of the image through the horizontal and vertical angle of view and the drone division angle. We can obtain the two points **hd** and **vd** according to the horizontal angle of view and the vertical angle of view, where **vd** is the merge position in the full images. This position can be combined with the split angle of the drone to obtain two points. According to the horizontal and vertical image size determined in Figure 5, the intersection point of the image can be obtained as shown in Figure 6.

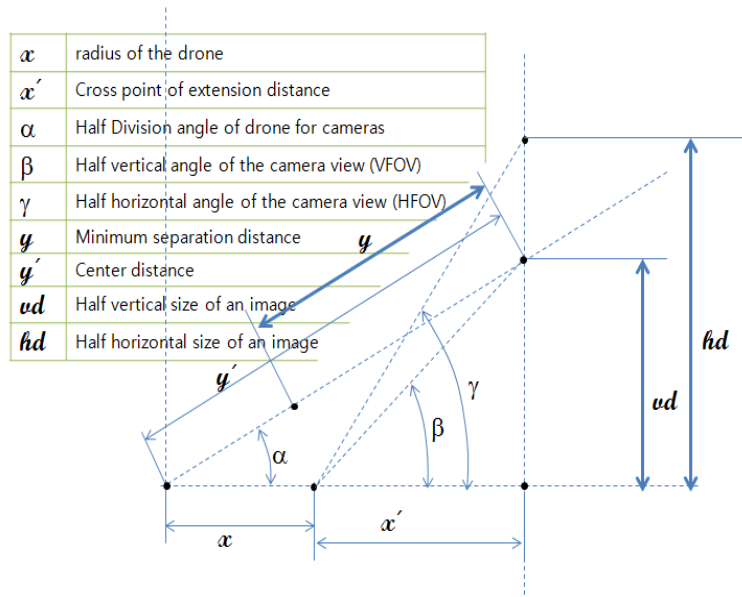


Figure 5. Relation of divided images according to horizontal and vertical angle of view in a drone

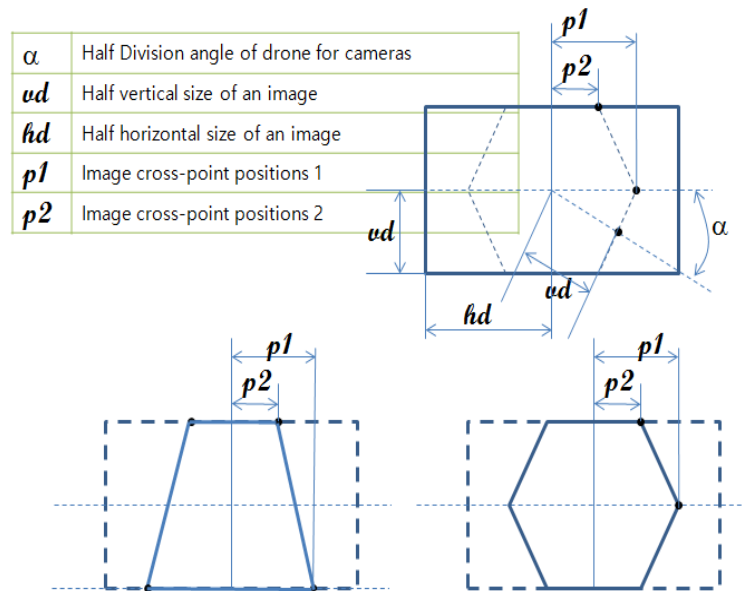


Figure 6. Relationship between two intersections between images

Through the analysis of the relationship between two intersections between images, we can define the equation for the intersection relation in the form of Equation 3.

$$p1 = \frac{vd}{\cos(\alpha)}, p2 = p1 - \left(\frac{vd}{\tan(2\alpha)}\right) \quad (3)$$

By merging the intersection points of each image, it is possible to acquire a single 360-degree image by removing redundant parts. Section 4 presents a drone design model to provide 360-degree simultaneous multi-video recording, taking into account the analysis results of Chapters 2 and 3.

4. Drone Design Model for 360-degree Simultaneous Multi-video Recording

The drone airframe design includes multiple cameras to form the drone body. In this paper, we constructed the model as shown in Figure 7 as a result of constructing 6x6 divided drone frame. When the camera has a horizontal angle of view of 120 degrees and a vertical angle of view of 90 degrees based on the half angle of the drone 1m in relation to the angle of view, the minimum distance for capturing the entire image is 1.73 m.

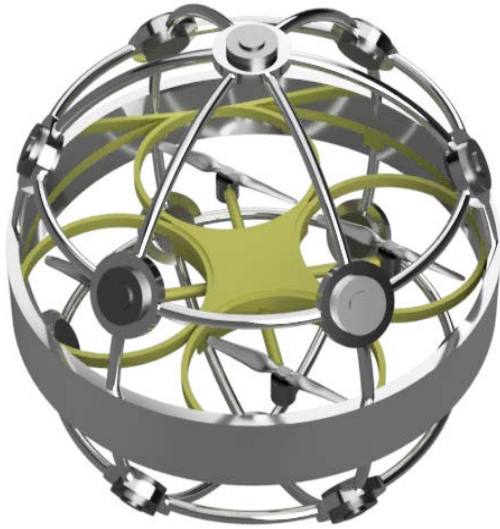


Figure 7. Design of a 6x6 split 360-degree simultaneous multi-video recording drone

In addition, the image size formed at the minimum separation distance of 1.73m according to the camera division angle has a vertical dimension of 2.73m and a horizontal dimension of 4.72m, and the two points for the image merging process have values of 0.78m and 1.57m around the center point. Based on the analyzed results, the merged result is shown in Figure 8. The image merging process efficiently merges the images generated by the drone, thereby minimizing the time required for merging and providing a real-time image. In addition, various viewpoints can be accessed based on the 360-degree image.



Figure 8. 6x6 divided multi-video recording drone and the result of the videos merging

5. Conclusions

Recently, the utilization of various purposeful drones

has been increasing in the 4th industrial revolution, and it is required to use real-time image information of various angles more efficiently. One camera approach mainly lacks real-time monitoring of various angles because there are blind spots of drone adjustment and monitoring, and VR and 3D approach also provides only one view at a time. Especially, in non-visibility flight environment, it is essential to acquire various viewpoint image information. In this paper, we proposed a drone airframe structure design model based on the multi-cameras approach required for 360-degree simultaneous multi-video recording for real-time operation and monitoring and the merge technology required for real-time image transmission. This model can be used in various application environments by providing real-time image service at various angles and providing the efficient monitoring and information access and communication environment required when operating the drone.

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REFERENCES

- [1] Stephane R, Narek MB, Kumar SS, Andreas W, Debadepta D, Andrew B, et al. Learning Monocular Reactive UAV Control in Cluttered Natural Environments. International Conference on Robotics and Automation. 2013 May;6(10):1765-1772.
- [2] Low KH, Lu G, Shixin M. A Preliminary Study in Managing Safe and Efficient Low-Altitude Unmanned Aircraft System Operations in a Densely Built-up Urban Environment. Air Traffic Management Research Institute, School of Mechanical and Aerospace Engineering Nanyang Technological University. 2014. Available from: http://atmri.ntu.edu.sg/Publications/Documents/Aviation_system_block/4%20A%20Preliminary%20Study%20in%20Managing%20Safe%20and%20Efficient%20Low-Altitude%20UAV%20Operations.pdf
- [3] SESAR. European Drone Outlook Study Unlocking the value for Europe, SESAR Joint Undertaking. 2016. Available from: https://www.sesarju.eu/sites/default/files/documents/reports/European_Drones_Outlook_Study_2016.pdf
- [4] Zaki M, Shakir S, Husin SH, Norafizah A. Altitude controller design for multi-copter UAV. International Conference on Computer, Communications, and Control Technology (I4CT). 2014 Sept; 2(4):382-387.
- [5] Bäumker M, Przybilla HJ, Zurhorst A. Enhancements in UAV flight control and sensor orientation. Proceedings of the International Archives of Photogrammetry, Remote Sensing and Spatial Information Science. 2013 Sept; 4(6):4-6.

- [6] Wojciech SM, Bohdan B. Flying n-copter with fuzzy logic control. Signal Processing Symposium (SPS), IEEE. 2013 Jun; 7(7):1-6.
- [7] Kenneth DS, Nicolas B. A Real-Time Adaptive High-Gain EKF, Applied to a Quadcopter Inertial Navigation System, IEEE Transactions on Industrial Electronics. 2014 Jan; 61(1):495-503.
- [8] Róbert S. The Quadrotor-Based Night Watchbird UAV System Used In The Force Protection Tasks. International conference Knowledge-based Organization. 2015 Nov; 21(3): 749-755. DOI: <https://doi.org/10.1515/kbo-2015-0126>
- [9] Ministry of Land, Infrastructure and Transport. 7 New Industry Promotion Policies – Drones. [updated 2017 Dec 21; cited 2016 Jan 27]. Available from: http://www.molit.go.kr/7works/content/sub_0201.jsp (website)
- [10] Cho J. Yoon Y. How to assess the capacity of urban airspace: A topological approach using keep-in and keep-out geofence. Transportation Research Part C: Emerging Technologies. 2018 July; 92:137-149. DOI:10.1016/j.trc.2018.05.001
- [11] Robert KT. Some relationships of camera angle to communicator credibility. Journal of Broadcasting & Electronic Media. 2009 May; 14(4):483-490.
- [12] Thomas AM, Joseph C, Jacob W. The effect of camera angle on source credibility and attraction. Journal of Broadcasting & Electronic Media. 2009 May; 21(1):35-46.
- [13] Ajulo, E. B., Akinyede, R. O., & Adewale, O. S. Security Threats and Privacy Issues in Vehicular Ad-Hoc Network (VANET): Survey and Perspective. Journal of Information, 2018; 4(1), 1-9.
- [14] Akande, P. I. Steady State Acceleration Model of Cosmic Ray in the Atmosphere. Review of Industrial Engineering Letters, 2014; 1(1), 16-24.
- [15] Akinyede, R. O., & Adedokun, J. A. Detection and Prevention of Phishing Attack Using Linkguard Algorithm. Journal of Information, 2018; 4(1), 10-23.
- [16] Akusu, O. M., Kiin-Kabari, D. B., & Barber, L. I. Palm Kernel Separation Efficiency And Kernel Quality From Different Methods Used In Some Communities In Rivers State, Nigeria. Journal of Food Technology Research, 2017; 4(2), 46-53.