Aerial Virtual Reality 360 Research-Creation

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***Abstract*—This paper presents a development of an aerial virtual reality 360 video capture approach. A drone was converted and retrofitted with a 360 spherical panorama camera for acquiring source aerial visual content. In this case study, an experiment of a 360-fly-by video was reproduced for the intended use of an event launching where user perception was being observed in terms of practicality and suitability. Utilizing a consumer 360 camera the Samsung Gear 360 and the DJI Inspire 1, it allowed the researcher to capture aerial 360-degree video. The paper documented the process of retrofitting the 360-camera onto the drone. Research findings on why certain drones are suitable for the 360-degree camera will be presented. A user study was conducted to gauge the usability for comparing aerial VR360 being experienced on hand-held multimedia tablets and head-mount-devices (HMD). In this paper we describe the proposed configuration and workflow of aerial 360-video and identifying its potential capabilities and limitation, a user evaluation study and directions for future work.**

Keywords—virtual reality 360, aerial, spherical panorama, user experience study, head mount devices, mobile applications

I. Introduction

Aerial Drones have been a topic that has ignited research since DJI came into the field with its consumer level drone back in 2013. Today, DJI drones are equipped with a Full HD camera and a gimbal that acts as a stabilizer for the camera in capturing visual data. Meanwhile, 360-degree video has reached the consumer as far as 2014 with Ricoh Theta, to name a few. Currently, Samsung's 360-degree camera called the Samsung Gear 360 has helped propel 360-degree video production into consumers' hands. It is no longer available just for the professional 360-degree video with their omni-cameras' rig. Just as flying and capturing visual data with a normal camera that comes equipped with the drone, movements of the drone will affect the way a visual data is captured. Drone movements such as taking off, landing, flying forward or reverse and flying sideways created a different result to the visual data.

The focus of this paper presents the analysis of the visual data in correlation to the drone movements, as part of its technical contributions. Post-production workflow for 360-degree footage from 360 camera used and modified on the drone is discussed in depth and also delivery of the 360 video to the audience. The project is supported with a pilot user study to understand the ease-of-use and usefulness of aerial 360 video be experienced in mobile and head-mount-device settings.

A detail discussion on the Samsung Gear 360 footage quality will be presented as well that covers from bitrate, frame rate, dynamic range tests, file compression and stitching software via the Samsung software and a third party software. The findings in this paper will also discuss the future implementation of aerial 360-degree video production with planned camera/drone movement for a beneficial results and better quality. Due to the Samsung 360 camera limitation, artefacts in the footage will also be presented to address a proposed solution.

II. Background

Our research builds on previous work related to aerial image and 360 content reproduction. Previous work has shown research interest in aerial 360 user experience [1] and spherical panorama 360 reproduction [2]. Preliminary study has revealed numerous aerial videos and photos has burst into the area of aerial drone with the recent advancement of aerial drone by one of the main industry producer DJI. Their drones are reliable and has gone through massive upgrade in their camera and gimbal and its affordability. However aerial 360 is very minimal in terms of creation and few that has done them are not documented in terms of their capabilities and limitations hence it became one of the aim of the research paper.

The main contribution of our work is creating customize aerial 360-degree video solution which can be easily adapted in virtual reality 360 user experience, and presenting what was the

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limitation with the setup and how it affected the end result of the aerial 360 video.

Manufacturers of 360-degree cameras can now be found anywhere. From Ricoh Theta, Insta 360 to Samsung Gear 360. All of these cameras are consumer level cameras that can be found anywhere for a very affordable price. These cameras are designed with dual fisheye lenses that is placed in opposite direction. The camera will then record simultaneously and resulted in a side by side footage of two lenses as per Figure 1.

Fig. 1. Dual lens raw footage.

The Samsung Gear 360 was used for this research as it provided the ease of use, affordability and reliability of the cameras regardless of its consumer level. The Samsung Gear 360 recorded with an average bitrate of 28mbps to 30mbps, which is very good considering that some DSLR cameras records at 60mbps bitrate with an option of 25mbps bitrate on certain codecs. The camera only records with a frame rate of 30fps and a resolution of 3840x1920. [3]

Samsung provides their own stitching software for owners of the camera. This is another reason why Samsung Gear 360 was chosen for this research with the stability of the stitching software compared with other brands.

III. Approach

This research article divides the approach to create the aerial 360 video content into two parts, production and post production. Production will cover the part of preparing the camera and retrofitting it to the drone. Whilst post production covers the part of stitching the footage and analyzing the result of such setup to capture aerial 360-degree video.

A. Production

This research chose the Samsung Gear 360 camera as the the camera is reliable with its stitching software and its ease of use due to is consumer 360 camera level in the market. Its size is also small thus mounting it on the drone did not created a weight problem that could affect the drone's flying ability. The Samsung Gear 360 camera has been tested on numerous on-ground shoot and gave good results considering it is a consumer level camera as per Figure 3. Stitching done by the Samsung software is also good, matches the two footage of each lenses as per Figure 4. Though the downside is the stitching software is only available in Windows, for the model we used which was the 2016 version, a Samsung S7 and above is needed to pair it with the camera. [4]

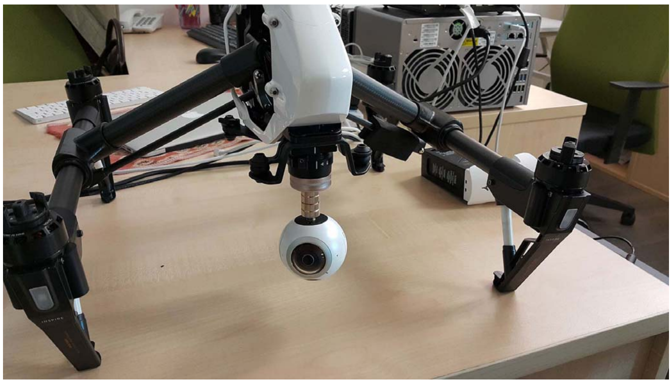

Fig. 2. Retrofitted DJI Inspire with Samsung Gear 360.

The DJI Inspire drone is ideal for pairing with the 360 camera, as the gear of the drone will lift up during flight thus not obstructing the view as per Figure 2. The aim of the aerial 360 video was to give a sense of flight for audience as if they are transported from one point to another by the aerial drone. With this in mind, the 360-degree view of what's below is crucial than the upper view which would be just blue skies and clouds. Retrofitting the 360 camera on a DJI Phantom drone created a take-off and landing challenge as it needs to be held by a person above their head due to its fixed landing gear.

The camera was mounted where the drone's camera is placed. With this, the pilot was flying relying only on line of sight of the drone, and the GPS positioning of the drone that was viewable on the monitor.

Fig. 3. Pre-flight check.

Fig. 4. Stitched image from the Samsung Gear 360.

The drone's flight movement was standard manouvre of a basic fly over the point of interests, taking off and landing. Height of the drone is also capped at 100 metres to maintain light of sight with the pilot. The challenge on this 360-degree video is not being able to see the results until it has been stitched. [5].

B. Post Production

Stitching the footage with Samsung Action Director is straightforward. The software is downloadable for owners of the Samsung Gear 360 camera. Auto stitch is performed automatically upon importing the footage into the software. The stitched footage is then exported (produced) into an AVC or H265 codec, which then can later be imported into Premiere Pro for more editing and fine tuning.

Stitching via Kolor Autopano Video Pro is possible although with the use of a custom template of panorama stitching, as the Kolor software only has presets for GoPro Cameras setup though the software does offer more stitching capability that user can adjust accordingly, unlike the Samsung Action Director that auto stitches the footages.

During analyzing the footage, we found that movement of the drone affected the 360 video shots as per Figure 5. As per our earlier research on Aerial Drone Videography with the Go Pro cameras, it had the same problems with this custom Aerial 360 Video. When conducting a take-off and landing shots, the drone was receiving wind pressure (inertia) that shakes the drone along with the camera. If using the current available gimbal and 2D camera on the DJI Inspire, this do not cause an issue with the footage as the camera is very stable. When accomplishing a fly through movement with the 360 setup, there seems to be an abrupt footage when the drone stops.

These problems might not be an issue if it happens in normal 2D videos, but when this occurred in 360 video it could result in a shaky footage and lead to nausea when viewed on a head-mounted device.

Fig. 5. Sample of aerial 360 videos with movement shakes.

These two issues could be solved by a motorized gimbal for the 360 camera that will balance the camera all the time. Though such solution is not available at the time of this writing.

Beyond this, another artifact in the footage was the appearance of the drone's propeller shadows as per Figure 6. This is caused by the position of the sun in relation to the drone and camera, and this problem also arises when shooting 2D video with the Aerial Drone. Though this could be solved with ND (Neutral Density) Filters attached to the camera lenses, this Samsung Gear 360 does not allow the use of ND filter on it not to mention that no such ND Filter is produced for this camera.

Fig. 6. Sample of aerial 360 videos propeller shadows.

The final result of the prototype in the form of 360 video have been used for a corporate event launch as an experimental use case as shown in Figure 7 and Figure 8.

Fig. 7. Example of a figure caption.

Fig. 8. Aerial 360 Video on Youtube

IV. USER EXPERIENCE STUDY

A pilot study was conducted to evaluate our prototype in conjunction with a corporate event launch using the 360 content we produced. We collected feedback from a set of 16 visitors, 8 females, and 7 males ranging in age between 18 to 62 years old. The aim was to measure the usefulness of the aerial 360 video in mobile tablet and head-mount-device configurations. The subjects were allowed to move freely and experience the aerial 360 content with the assistance of an experimenter. The experiment conductor explained the processes and provided a complete demonstration. Each participant completed the tasks in about 3 minutes. We used a within-subject experimental design. Participants were requested to experience the content twice in two conditions in random sequence. The two conditions involved using a 10.1 inches Android tablet (Samsung manufactured Tab 2 GT-P5100), and also experiencing the HMD configuration shown in figure 9 (using mobile computing device of Samsung S7 Edge G935FD [6]). After running the trials we got participant feedback on how easy it was to use the system. This was done by collecting qualitative feedback in response to the questions shown in table 1. Answers were captured on a Likert scale of 1 to 7 in which 1 was "strongly disagree" and 7 "strongly agree". Our key interest was to understand the perceived ease-of-use and usefulness of the prototype by the participants, and how they described their experience with our system.

Fig. 9. Aerial 360 video with mobile tablet and HMD user experience.

Table 1: Survey questions

Q1	I found it easy to use
Q2	I found it natural to use
Q3	I found it useful
Q4	I found it physically challenging
Q5	I found it mentally challenging
Q6	I found the content immersive

Figure 10 shows the average results of the condition 1 using mobile tablet (C1) and condition 2 using HMD (C2) survey questions. A Wilcoxon Signed Rank Test was used to analyze the results to check for significant difference between the results of the using visual (C1) and non-visual interfaces (C2).

Q1, using a two-tailed test we found that participants felt that the mobile tablet device is significant easier to use than the HMD, $Z = -1.48$, $p = 0.14$. For Q2, finding the interface natural to use, there was a nearly significant difference between C1 and C2, with $Z = -0.84$, $p = 0.4$. There was significant difference between conditions in terms of how reliable participants felt each condition was (Q3), $Z = -1.22$, $p = 0.22$ HMD are more useful than mobile tablet. In terms of the physical challenge, participants felt that C2 are significant in physically challenging (Q4) than the visual condition (C1), $Z = -1.06$, $p = 0.29$. Next, C2 was felt to be more mentally challenging (Q5) than C1, $Z = -1.21$, $p = 0.22$. Finally, C2 was viewed as being more immersive (Q6) than C1, $Z = -2.93$ $p = 0$

Overall, these results show that the HMD (C2) are better than mobile table (C1). The results are shown in figure 10.

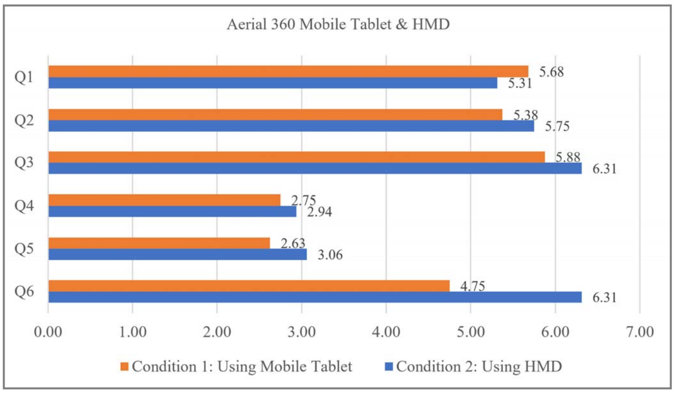

Fig. 10. Results comparing two conditions (mobile tablet and HMD)

In addition to the survey, we asked participants for their comments on the system usability. Users said they liked how the "I enjoy the 360 content where I can look around freely.. ", "..very interactive..", "can I learn how to create these content?", and "..really created an adventurous experience.".

However users also felt that "..It will be important if we are able to have clearer image quality...", "this looks unique but I think I need some time to get used to it", "I feel dizzy when I view the content for too long (for HMD)" and "Since i wear specs i had a bit of difficulty putting it on (for HMD)". About 43.75% of the users experience some level of dizziness when using HMD, and none had such difficulty when using a mobile tablet.

When asked about their AR/VR experience on a Likert scale of 1 to 7, where 1 = not very much, and 7 = very much, the average score was 3.25. Some participants were new to VR360 and were not sure how to operate it consistently. During each trial, we observed that the strength of the internet connection affected the stability of the video streaming. Some users expressed that were interested in trying the content in their own mobile devices and asked if there is any accessible control or navigation available to them in HMD mode.

Participants also provided the several ideas for improvements:
i. Being able to choose between online or offline application.
ii. Content-provider devices should be preloaded with content.
iii. A distributable link can be provided for sharing purposes.
iv. High-speed internet is provided by the event organizer for improved user experience.

V. Conclusion and Future Work

In production consideration, a gimbal is required to maintain the 360 camera stability. The gimbal will balance the camera and preventing it from tilting over. As in the case of 360 video, the horizon of in the shot has to be maintained during the shoot. A 360 camera that has a feature of a built-in ND filter would be good to avoid having the drone's propeller shadows in the shots on some certain angles.

A professional capability camera would be a great upgrade for the 360 aerial data capture, such as the Nokio Ozo, Insta360

Pro, Go Pro Omni, though that could also affect the drone selection that can carry them. For future study, we will also explore other solutions for improving the experience of the virtual reality 360 and hybrid approaches that combine 3D and image-based spherical panorama videos.

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