Overview of drone cinematography for sports filming

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This paper is an overview of the current state-of-the-art (SoA) in drone (UAV) cinematography. A taxonomy of UAV shot types is developed. Limitations of single-UAV shooting are presented, advantages of multiple-UAV shooting are discussed and a potential scenario is described. The overall focus is on cinematographic coverage of sports events, but most of the contributions are relevant to all UAV cinematography applications.

A recent research trend is the development of end-to-end systems able to execute specific single-drone shooting missions. In [1], a tool is presented for computing drone trajectories and camera parameters using example "key-frames" specified by the user. Subsequently, a UAV is guided outdoors so as to autonomously capture the desired footage, while obeying cinematographic rules. Static shots based on visual composition principles and canonical shots, as well as transitions between shots are computed automatically. In [3], the authors present an autonomous system that calculates the appropriate number of drones, in order to maximize the coverage of targets from appropriate viewpoints. Little research has been performed focusing on intelligent multiple drone shooting/cinematography [2, 4].

Several standard types of UAV/camera motion trajectories have emerged since the popularization of UAVs. UAV camera motion types involving actual target filming are depicted in the Figure below:

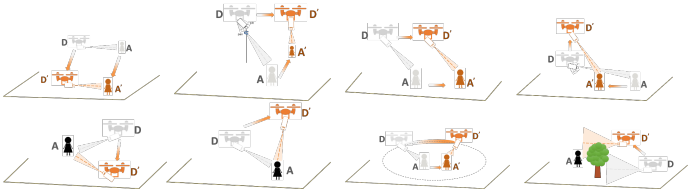

Figure 1: From left top to bottom right: Lateral Tracking Shot (LTS), Moving Aerial Pan with Moving Target (MAPMT), Chase (CHASE), Pedestal Shot with Target (PST), Fly-By (FLYBY), Fly-Over (FLYBY), Orbit (ORBIT) and Reveal Shot (RS)

Current practices typically employ a single drone for shooting. In offline shooting with full post-production editing, the single available drone works at different times to produce several takes. By having only one drone, full scene coverage from different viewpoints at the same time instance is impossible, leading to less raw material available for editing. Alternatively, multiple shooting sessions are needed, which are vulnerable to varying lighting conditions. One-drone shooting of live events bears all disadvantages of shooting a live event with a single hand-held camera, e.g., no extensive editing work can be performed in post-production. Additionally, "dead" time intervals arise during shooting, due to drone traveling between different viewpoints, battery autonomy limitations etc.

The above limitations can be overcome by using multiple drones, which offers the following advantages: a) a broader range of viewpoint angles is available, leading to enhanced richness and artistic quality of event coverage, b) scene overview from above can be shot simultaneously with principal footage acquisition c) scene coverage can be extended in time and space, by exploiting drones relays, d) novel cinematography effects become possible, enhancing the viewer experience, e) the need for expensive shooting infrastructure, e.g., spider-cams and helicopters, is reduced.

In Figure 2, a multiple drone scenario, namely the "Dancing Drones" is depicted. At all stages, all drones should never lose focus on rowboats.

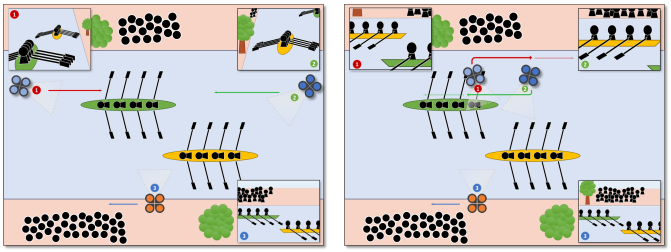

Figure 2: The "Dancing Drones" scenario.

- Drone 3 is permanently flying parallel to the boats at constant altitude performing LTS taking medium close-up throughout the race.
- Drones 1 and 2 fly at same altitude, starting from a fixed distance between one another. Drone 1 is placed in front of the two rowboats, while drone 2 is placed behind them, so the boats are exactly halfway between the drones.
- Drone 1 flies much slower than Drone 2 (the one that "catches up") in the opposite direction (heading to each other and the boats which are halfway). Both cameras focus on rowboats (first half of two opposite Fly-Overs).
- Shortly before they would collide (ideally directly above the boats) they avoid hitting by moving horizontally in different directions without slowing down and losing focus on the boats (MAPMT).
- After they passed, both drones continue moving until Drone 2 reaches the initial position of Drone 1, and Drone 1 the position of Drone 2 (second half of 2 opposite Fly-Bys).
- Here, the process restarts: both drones slow down and change their flight directions, heading towards each other again.

As can be observed, conceptually advanced multiple drone scenarios (e.g., the dancing drones) can be viewed as constrained combinations of existing single-drone shot types, essentially defining multiple drone cinematography patterns, that can be followed in many media production scenarios. Therefore, multiple drone cinematography allows many such scenarios to be defined, opening an exciting new field for technical and industrial applications.

[1] N Joubert, J.L. E, D.B. Goldman, F Berthouzoz, M Roberts, J.A. Landay, and P. Hanrahan. Towards a drone cinematographer: Guiding quadrotor cameras using visual composition principles. *ArXiv e-prints*, 2016.

[2] T. Nägeli, L. Meier, A. Domahidi, J. Alonso-Mora, and O. Hilliges. Real-time planning for automated multi-view drone cinematography. *ACM Transactions on Graphics*, 36(4):132:1–132:10, 2017.

[3] A. Saeed, A. Abdelkader, M. Khan, A. Neishaboori, K.A Harras, and Amr. Mohamed. On realistic target coverage by autonomous drones. *ArXiv e-prints*, 2017.

[4] A. Torres-Gonzalez, J. Capitan, R. Cunha, A. Ollero, and I. Mademlis. A multidrone approach for autonomous cinematography planning. *Third Iberian Robotics Conference (ROBOT)*, 2017.