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Unmanned Aerial Aircraft Systems for transportation engineering: Current practice and future challenges

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ABSTRACT

Acquiring and processing video streams from static cameras has been proposed as one of the most efficient tools for visualizing and gathering traffic information. With the latest advances in technology and visual media, combined with the increased needs in dealing with congestion more effectively and directly, the use of Unmanned Aerial Aircraft Systems (UAS) has emerged in the field of traffic engineering. In this paper, we review studies and applications that incorporate UAS in transportation research and practice with the aim to set the grounds from the proper understanding and implementation of UAS related surveillance systems in transportation and traffic engineering. The studies reviewed are categorized in different transportation engineering areas. Additional significant applications from other research fields are also referenced to identify other promising applications. Finally, issues and emerging challenges in both a conceptual and methodological level are revealed and discussed.

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Introduction

Traffic surveillance and monitoring has been one of the main tools for Transportation Managers and Engineers for years and an integral part of traffic management and control strategies (Papageorgiou et al., 2008). Several algorithms or systems have emerged to track moving object and analyse traffic, such as (Hsieh et al., 2006; Liu et al., 2008; Shukla and Saini, 2015; Sivaraman and Trivedi, 2013). The visual perspective of the manner traffic (either vehicles or people) evolves over space and time may assist the understanding of recurrent traffic conditions, the efficient management of pedestrian and vehicle traffic, as well as the traffic and demand management under unexpected transportation network conditions (e.g. extreme congestion, adverse weather conditions, riots, terrorist attacks), that may severely deteriorate the performance of the transportation networks and affect the security and safety of users.

Collecting visual information for large networks can be a challenging procedure. Installing stationary cameras to monitor the extent of a transportation facility has been a successful practise for years. Nevertheless, several practical issues may emerge; for example, there are cases where the area to be monitor is large and cannot be covered from static cameras. Moreover, installing stationary cameras and supplementary infrastructure can sometimes be too costly, especially when an area does not need to be monitored anymore.

Even if the cost parameter from the problem of the transportation infrastructure monitoring could be alleviated, the problem of acquiring visual information and gathering data under the emergence of unexpected events is still not addressed. An extreme event may occur at any place and any time. The response to such events should be made in a timely manner to reduce their effects to the transportation system. Evidently, from an emergency response perspective, a setting of static cameras fails to provide a clear picture of the unexpected extreme event, as the setting is specific usually with limited ability to cover a transportation system (see Table 1).

Additionally, in rural environments, where problematic areas are more sparse, operators would sometimes have to deal with large time intervals between identifying the situation, assessing all necessary steps and lastly taking measures to tackle it, losing valuable time for safety and security and/or resources allocation. Therefore, some practitioners would use ground vehicles as a supplement to the input coming from cameras along the network. Sometimes though, the area of interest may not be accessed immediately, for example when a road accident causes heavy traffic jams upstream the arterial or when the emergency area is not accessible. Similar conditions may arise in an urban setting, where dense road networks sometimes add excessive delay for an emergency vehicle to reach its destination and provide first aid.

Until now, Manned Aerial Vehicles (MAV), usually helicopters operated by the police or air medical services, have been the most appropriate means of providing live picture and information to the control centers and/or provide first aid in an utmost situation. Except for the fact that – in principle - a MAV has high fixed and operation costs, there are many cases that sending a helicopter with people inside or extremely costly equipment, over the area of interest is not always feasible, due to high risk.

Recently, Unmanned Aerial Aircraft Systems (UAS) have been proposed as an alternative in order to overcome the above-mentioned limitations and shortcomings of current practices. A UAS consists of three components: (1) the aircraft, which is defined as an Unmanned Aerial Vehicle (UAV or drone); (2) communication and control; and (3) the pilot. This paper aims to review research dedicated to using UAS in transportation and the advantages of airborne video as a means for acquiring high quality naturalistic data for both practitioners and researchers. The structure of the paper is as follows. First, the advantages of the UAS are described and their technical characteristics that can make them a game changer in Intelligent Transportation Systems (ITS) infrastructure monitoring. Following, we describe some of the latest advances in their technological aspects and important applications that UAVs have already been used for. Then, an analytical review of papers for airborne video footage is conducted. Finally, some issues and challenges concerning UAVs safe and effective integration into ITS applications are discussed.

Table 1
Comparison between static cameras, MAV and UAV.

	Static cameras	MAV	UAV
Length coverage	Low	High	High
Security/Privacy	Medium	Medium	Low
Cost (acquiring and maintenance)	Low	High	Low
Multiple uses	Low	High	High
Energy efficiency	Low	Low	High
Deployment	Low	High	Low
Operational time	High	High	Low
Operation under adverse weather	Medium	Low	Low
Risk	Low	High	Medium
Endurance	High	High	Low
Video post-processing skills	Medium	High	High
Data transfer, communication and storage	Low	High	High
Operation skills	Low	High	Medium
Training requirement	Low	High	Medium
Complexity	Medium	High	Medium