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Brian Cusack

Auckland University of Technology, brian.cusack@aut.ac.nz

Reza Khaleghparast

Auckland University of Technology, reza.khaleghparast@aut.ac.nz

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EVALUATING SMALL DRONE SURVEILLANCE CAPABILITIES TO ENHANCE TRAFFIC CONFORMANCE INTELLIGENCE

Brian Cusack; Reza Khaleghparast
Auckland University of Technology, Auckland, New Zealand
brian.cusack@aut.ac.nz, reza.khaleghparast@aut.ac.nz

Abstract

The availability of cheap small physical drones that fly around and have a variety of visual and sensor networks attached invites investigation for work applications. In this research we assess the capability of a set of commercially available drones (VTOL) that cost less than $1000 (Cheap is a relative term and we consider anything less than $5000 relatively cheap). The assessment reviews the capability to provide secure and safe motor vehicle surveillance for conformance intelligence. The evaluation was conducted by initially estimating a set of requirements that would satisfy an ideal surveillance situation and then by comparing a sample of drone specifications. The search is for identifying a drone that is fit for purpose. The conclusion is that more than $1000 needs to be spent on the drone and the resources for effective observation but less than $3000 in total is sufficient for the work application. The result and the analysis of traditional surveillance networks suggests that such drones can provide a low entry risk for additional benefits; and intelligence to those responsible for compliance on our roads.

Keywords
Surveillance, Risk, Drones, Performance, Value

INTRODUCTION

Traffic conformance audit on roads is maintained by a mixture of surveillance devices and techniques. A compliant vehicle is one which delivers the transportation service within a profile of measurable attributes that conform to the usage contract. These attributes include proximity, speed, mechanical safety, registration, licencing and so on. The usage contract has a wide variety of requirements that cover different vehicles, human factors and situations. For the purpose of research the scope is limited to intelligence on movement and registration conformance. The attributes are currently measured by a variety of sensor networks that are fixed (eg. Fixed cameras, hand held cameras, observation posts and so on) and mobile (mounted cameras, moving cameras, variable observations and so on). The prioritisation by highest safety risk sees sensor networks deployed to high failure locations that include statistically targeted crash areas, vulnerable persons areas (eg. Primary schools, residential care units and so on), compromising human factors (eg. Around events, venues, behaviours and so on); and further resolution of priority can be time based where resources spring up and then are moved elsewhere or are stored (eg. For holiday periods, peak flow times and so on). Traditionally surveillance is viewed as a network that meshes information capture within manageable resource parameters (Dais et al., 2013). The central management problem is optimising resource expenditure against the cost of obtaining, storing and processing the information (Ahmed and Hossain, 2012). Also legal and social compliance issues impact the scope and usage of a surveillance network. As a consequence the surveillance network covers and focuses on prioritised instances but leaves much detail out of scope. Hence the combination of fixed and mobile cameras is sufficient to observe a percentage of high value instances. The problem however is more complex. The sensor network can be time dated where the priority zone reports a story from a past epoch of urgency, humans learn from the sensor network and apply avoidance behaviours, the cost versus information trade-off may deliver too little useable intelligence and so on (Junjo and Cao, 2007). These weaknesses in contemporary compliance sensor networks require redress in order to improve safety and responsiveness to changing situations.

In this research we evaluated theoretically the opportunity to introduce cheap drone mounted cameras into the traditional mix of mobile and fixed cameras that provide intelligence on traffic conformance to contract. The advancement of technologies has allowed high performing low cost light weight cameras to be attached to equally low cost and light weight flying machines that have high end communications controls, remote programing, sensor guidance and many sophisticated operational attributes. These advancements are relatively new applications that are now integrated into a single delivery system and commercially available. Information may either be streamed real time or stored in the drone memory as photographs or continuous video or video clips. The relative motion of any object in the camera range can be measured by frame rates and converted to velocity for speed conformance audit. A drone based camera has the advantage of operating as a covert or an overt information stream thereby influencing human factors by presence or association with the traditional surveillance network (eg. As part of road signage warnings, TV advertising the capability and so on). In the covert operation mode the problem of human learning and avoidance behaviours is resolved and the information stream is uninterrupted.

The paper is structured to review current research in visual surveillance and the application to surveillance networks used for traffic conformance to contract. The potential of drones costing less than $1000 to add value for surveillance is assessed by comparison with an ideal work model. The limitations identified allow the evaluation of alternative solutions including slightly more expensive but close to fit for purpose solutions; and the development of scenarios that accommodate the technology limitations. The potential for implementation and operational frameworks is discussed as a design and delivery solution for improved intelligence and relevance to a global economic and safety problem.

THE SURVEILLANCE GRID

A space in which surveillance occurs is often called a grid to describe the three dimensional co-ordinate system that defines the capability and the meshes for information (Muller and Smoki, 2005). A grid has a geographic footprint and sensor networks that receive information from anywhere in the electromagnetic spectrum (Leykin et al., 2007). These data are reported to a database and analytic tools produce reports based on the information requirements. In a retail store for example, visible and invisible cameras are positioned in such a way that the highest priorities in the risk register are secured to the point where no more resources will be expended (Ahmed and Hossain, 2012). The cameras collect data in the visible light and the infrared spectrum sectors. The resources of the system are managed by triggers that activate resource expenditure against the risk register. The trigger calculations are made by algorithms that process the data from sensors and match the results against stored profile information. Movement or patterns of objects trigger focusing, faster frame rates or the display of signals for agent action (Makris and Ellis, 2005). Such surveillance systems are consistent with the concept of placing items of interest within a grid space for observation. Goradia and Ning (2012) describe the surveillance grid as a space for “perception and reasoning”.

Current research in surveillance has moved on from multi-camera and multi-sensor advancements and towards information processing for pattern recognition. The central problem is resource costs for the information gained (Ahmed and Hossain, 2012). Video and other camera hosted surveillance data amounts to big data with enormous quantities that may or may not be relevant to an event. Consequently research is pushing forward on two fronts: one to improve the quality of image data and the other to improve recognition algorithms. In this way the processing and storage capacity improvements can be exploited to improve the quality of intelligence gained. Dais et al. (2013) and Muller and Smoki (2005) both explore improving motor vehicle surveillance functionality and Chen et al., (2008) the performance of fixed cameras. Researchers are looking to develop more intelligent camera functionality by enhancing the software capability behind the camera. In this way image resolution and the information processing of different types of image and content search can be made more effective. The consequence is that many policing surveillance grids for traffic conformance to contract are working at an optimal technology to work function rate. The ideal situation is where the human factors responsible for traffic conformance learn the appropriate behaviours and operate safely within the conformance requirements. The effectiveness of the current optimised socio-technical system of surveillance can be compromised by the potential for learned avoidance behaviours. As such human factors may influence conformance when for example a fixed camera, a mobile patrol or a signal alert triggers the required behaviour. At other times the behaviour may be non-compliant. To manage such occurrences the addition of mobile and irregular (eg. Drone mounted) camera surveillance has potential to enhance conformance.

The surveillance grid requires adequate communication channel bandwidth to function efficiently (Chen and Safar, 2007). Images have much greater payload than text based messages and consequently require greater communication resources. The exception based filter for the production of images reduces the number but the quantity can still be large (Bakhtari and Naish, 2006). Policies regarding retention of frames for evidential purposes may impose limitations on the use of system and impact the utility when buffers fill. One procedure is to let a camera run until the memory chip is full and then physically remove it for analysis and replace it with another. With better band widths all exception images can be streamed continuously to a central processing unit for analysis. The size and weight of cameras has reduced and the functionality increased. Consequently surveillance has become easier and can be more economical and in more locations than previously (Dais et al., 2013; Fong and Hui, 2001). Fong and Hui (2001) forecast the integration of surveillance networks with a multiplicity of communication networks, such as the Internet, Cell networks and satellite based networks. Today these innovations have been implemented and other economical solutions are also available.

FOUR CHEAP DRONES REVIEWED

Four drones advertised at $1000 or below were selected from vendor websites for evaluation of the advertised performance data. Flight tests were also undertaken to assess the drone in action: one valued at $350 (Drone B) and another at $2995 (Drone E). The tests were undertaken to verify the vendor performance claims and to observe performance and issues in action. These experimental data helped with our learning and extended our understanding of the problem being addressed. For example we had not considered the wind below 5 knots to be an issue in the stability and control of a drone. The cheap light drone became unusable in gusts and moderate winds because of stability issues for the camera and subsequent blurring of images. It also made frame based speed calculations more difficult. The more expensive Drone was not in the under $1000 category but was tested to contrast the cheapest ones' performances and to have an artefact closer to our ideal forecasted capability for conformance to contract evaluation.

The research proceeded by making a conjecture regarding the ideal capabilities for a cheap Drone that could perform compliance to contract evaluation for speed and registration. Our wish list is in Table 1. The purpose of the conjecture was to set a target capability as reference for comparisons from which evaluation could proceed.

Table 1: The Ideal Cheap Drone

Ideal Drone Capabilities Conjecture	
Cost	Less Than $1000
Power	Electric
Weight	Under 300gm
Size Maximum	400mm x 400mm x 30mm
Endurance	3 hours
Recharge Rate	1.5hrs
Speed	40km/h < v < 80km/h
Range	>3Km (out of sight)
Camera Resolution (daylight)	Character recognition from 150m
Frame Rate Calculator	Calculates moving image speed
Communications	Multi-channel Wi-Fi (auto hop) and HFR
Control	Visual, GPS, AI learning, touch screen GUI
Storage Capacity	1Tb
Blade protection	Yes
Fail Safe Return to Base	Yes

We also wrote a scenario for the ideal operational capabilities a drone or set of them should have for integration with current policing surveillance grids (Table 2).

Table 2: Work Case Example

Work Case Scenario
A policing unit may operate singular or multiple drones from buildings, road side locations or from police vehicles to enhance current visual surveillance practices. Each drone has the ideal characteristics (table 1) and can be deployed over a >3km working radius to gain traffic conformance intelligence. The current capability of roadside stationery vehicles can be enhanced by adding pre-programmed drones to gather intelligence and feed it back to a central database while the officer is performing the usual traffic patrol duties. The continuous work flow can be managed so some drones are charging while others are working over an eight hour day. The information flow of big data is managed by the drone only communicating images of exceptions. For example vehicles under and over the speed tolerance control are reported; and expired registration stickers. Everything else is not transmitted or recorded.

The following four cheap drones (A to D) were selected from the many available. Each has the ability to take single shots or video under the control of the operator. The on-board storage capacity reported can be enhanced by using it as a buffer that dumps to a central external unit (such as a laptop and so on). The brands are not disclosed or identities in this research.

Table 3: Drone Literature Analysis

	Drone A	Drone B	Drone C	Drone D	Drone E
Cost	$95	$350	$665	$995	$2995
Power	Battery	Battery	Battery	Battery	Battery (2)
Weight	150gm	300gm	410gm	600gm	1300gm
Size Maximum	30mm x 30mm x 30mm	500mm x 500mm x 150mm	350mm x 350mm x 200mm	400mm x 400mm x 250mm	400mm x 400mm x 250mm
Endurance	12 minutes	15minutes	25minutes	25minutes	50minutes
Recharge Rate	1.5hrs	1.5hrs	1.5hrs	1hr	30minutes
Speed	35kmh	45kmh	45kmh	60kmh	60kmh
Range	250m	500m	500m	1.5km	3.5km
Camera Resolution (Daylight)	Character recognition from 50m	Character recognition from 50m	Character recognition from 50m	Character recognition from 80m	Character recognition from 100m
Frame Rate Calcs	No	No	No	No	No
Communications	Wi-Fi	Wi-Fi	Wi-Fi	Wi-Fi	Wi-Fi
Control	Visual, Uses iPad, touch screen GUI	Visual on screen, Uses 2 joysticks and line of sight. Physical button controls.	Visual, Uses iPad, touch screen GUI	Visual, GPS, touch screen GUI, out of sight programmable.	Visual, GPS, touch screen GUI, out of sight programmable.
Storage Capacity	4Mb	8Mb	64Mb	16Gb	64Gb
Blade Protection	No	Yes	No	No	Yes
Fail Safe	No	No	Yes	Yes	Yes

TESTING RESULTS

The live testing of Drone B and Drone E was exploratory flying to identify potential issues and problems in practice.

Table 4: Drone B Analysis

	Drone B	Characteristic	Improvements
Cost	$350	Cheap	
Power	Battery		More Batteries
Weight	300gm	Light	Failures in winds
Size Maximum	500mm x 500mm x 150mm	Large for weight	Reduce drag profile
Endurance	15minutes	Too short	More Batteries
Recharge Rate	1.5hrs	Slow	Better quality

Speed	45kmh	adequate	
Range	500m	Ok for close range	Out of sight capability
Camera Resolution	Character recognition from 50m	Works ok for range	
Frame Rate Calcs	No	Difficult to add	Laptop communications
Communications	Wi-Fi	Sufficient in normal conditions	More options for greater range
Control	Visual on screen, Uses 2 joysticks and line of sight. Physical button controls.	Hard to manage and stabilise in low winds and above	Needs GPS, touch screen GUI, out of sight programmable.
Storage Capacity	8Mb	Ok for 8000 cars	
Blade Protection	Yes	Good for operator	
Fail Safe	No	None	Required

Table 5: Drone E Analysis

	Drone E	**Characteristic**	**Improvements**
Cost	$2995	>$1000	Cost
Power	Battery (2)		
Weight	1300gm	Resists low wind	
Size Maximum	400mm x 400mm x 250mm	Balanced for work	
Endurance	70minutes	adequate	More Batteries
Recharge Rate	30minutes	fast	
Speed	60kmh	adequate	
Range	3.5km	adequate	Out of sight capability
Camera Resolution	Character recognition from 100m	adequate	
Frame Rate Calcs	No	Easy to add	Code it in
Communications	Wi-Fi	adequate	HFR option
Control	Visual, GPS, touch screen GUI, out of sight programmable.	Easy to program, send off to work and return	

Storage Capacity	64Gb	Adequate with management	
Blade Protection	Yes	Good for operator	
Fail Safe	Yes	Return to Base	

DISCUSSION

The comparison of the Drones B and E; and comparison to the ideal (table 1), shows that the capability of drones under $1000 is inadequate for serious workloads. They are not ruled out for specialist situations such as surveillance of high density traffic situations where in 25 minutes 8000 conformance images could be shot and returned for analysis. Drone D has the capacity to be used for serious but limited work situations. The main limitation is the battery endurance. The problem could be overcome by wiring in more light weight batteries to increase flight time but it would still be less than the ideal case. Another solution would be to run two identical drones in series and to have spare batteries recharging. This would allow minimal downtime for battery swapping while having continuous work flow; but the solution would still fall short of the ideal work situation; and again the cost ($2000) is in excess of the ideal. The most serious concern is the vulnerability to weather conditions by the drones under 600gm. Drone B had instructions not to be used in the rain and it also became difficult to control in the wind. These matters are unacceptable in a work situation. The conclusion is that many of the shortcomings in drones under $1000 can be compensated and for limited tasks they have application. However more money has to be spent than $1000 to achieve a fit for purpose work system solution, and more software developed to achieve the ideal case.

In the out-of-the-box form each drone fell short of the ideal case on one issue; that of on-board processing. All drones had adequate cameras, storage capacity and communication distance. Obviously Drone A was weak on each count but it still had the functionality and performed within its declared envelope of surveillance capability. However traffic conformance to contract requires specific but easy to code information management functionality. It requires computation of object speed from the movement through the video frames. These frames do not have to be resource hungry and streamed in real time but simply computed, the vectors resolved and exceptions recorded for transmission or storage or both. In all the drones there is sufficient on-board storage capability to buffer frames so that the evidence to support an exception can be retained for all computations; and the normal traffic frames can be deleted once the state is computed. The code to achieve the functionality is not difficult but only Drones B, D and E had the pins available to bolt such a computational module onto the mother board. The other solution is for all drones to stream the live frames back to a central computer such as a laptop in a patrol vehicle where the computation can easily be automated and completed. Similarly for registration conformance the licence plate identification can be streamed for character recognition processing and central database reference.

By elimination Drone E provides a functional solution to the work case scenario. Where it falls short on endurance time, two drones can effectively be used in series because of the short charging time. This would mean two drones would cover an 8 hour shift for a cost that is substantially less than a hand or dash board surveillance camera. We found in practice that although the straight line speed of the drones were not high they were highly manoeuvrable within the three spatial dimensions and could hover above a highway out of sight of drivers photographing and computing the conformance attributes for every passing vehicle in four lanes (both directions). The drones could quickly be moved into spaces not covered by the usual surveillance grid. Drone E had a functional communication range of 3.5km which was more than what was required in the work case scenario. It also had capability to follow preloaded maps by GPS navigation to avoid obstacles and move around pre-determined way points. One drone could be launched 30 minutes before the other returned for charging and if four were employed (as per table 1) and the patrol vehicle moved between locations the drones could stay airborne (less a small battery swap time) and thus covering a huge geographic space in a day’s work. Another work scenario is to send the drones from a district base station for 80 minutes at a time and for distances up to 50km to complete surveillance and then return to base to download the data for processing. In each situation the human factors are not replaced but the capacity of an enforcing authority to provide conformance to contract surveillance is greatly increased.

CONCLUSION

The conformance of vehicular traffic on roads to the usage contract is a safety and an economic problem that requires innovative solutions. We have demonstrated in this research that relatively cheap drones can be added to the current surveillance network to add value for visual and speed intelligence. Other intelligence may be gained as the range of spectrum are extended in the drone sensor network. Each potential information stream requires further analysis to determine the most effective host for the information extraction and the value a drone may or may not add for conformance intelligence. The scope of the research has been deliberately narrow so that two critical attributes (speed and registration) could be evaluated. Further research can include other spectra information streams and also strategic development of capabilities to manage large data sets effectively.

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