Real-Time Monitoring Of Utility Right-Of-Ways Using Autonomous Unmanned Aircraft Systems

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Abstract – The United States is criss-crossed by an extensive network of surface and subsurface utility corridors. Despite the best efforts of utility companies to mark these right-of-ways and to continually inform property owners of their existence, the underground infrastructure can still be damaged accidentally by third parties operating construction equipment within the utility corridor. In order to mitigate these threats, the utility companies must routinely monitor these corridors using manned low-flying aircraft as well as ground vehicles. Mercury Computer Systems has teamed with Intellitech Microsystems and American Aerospace Advisors to develop an autonomous, real-time, unmanned aircraft system (UAS) to monitor these right-of-ways at a much reduced cost.

Keywords: UAS, utilities, right-of-way, monitoring, real-time

INTRODUCTION

Utility right-of-ways in the continental United States extend for tens of thousands of miles in all directions. These corridors are used to transport electricity, crude oil, refined petroleum products and natural gas. Many of the right-of-ways, especially those carrying high tension electrical transmission lines, are clearly visible to anyone near them. However, oil and gas pipelines are primarily run underground and often have agricultural fields or pastures located directly over the right-of-way. The utility companies take great effort to mark these hidden right-of-ways with signs and to routinely inform and remind the property owners of the pipe's existence. Despite these efforts, the utility infrastructure can still be damaged accidentally by third parties operating construction equipment in the right-of-way. Such damage has the potential to threaten lives and to cause millions of dollars in property damage.

In order to mitigate these threats, the utility companies must routinely monitor the entire extent of their right-of-ways. This monitoring typically exists of making a visual inspection of the entire corridor every week using a combination of low flying aircraft and ground vehicles. The pilots and drivers look for dangerous or suspicious activity and radio the location of anything they detect to dispatchers on the ground. This process is very expensive given that it must be done weekly over thousands of miles of right-of-ways.

Mercury Computer Systems has teamed with Intellitech Microsystems and American Aerospace Advisors to develop an autonomous unmanned aircraft system (UAS) to monitor utility right-of-ways. The system is based on Intellitech's Vector P UAV which can safely and economically fly hundreds of miles along a utility corridor and, in real-time, automatically detect many of the likely threats that may exist. An on-board disk drive also stores a video stream of the entire flight which can then be post-processed using classical change-detection algorithms to identify possible threats that were too subtle to detect in real time. The mission planning, mission control, collision avoidance and post processing are all hosted on Mercury's VistaNav ground station. This new UAS offers significant cost savings when compared to using piloted aircraft for monitoring utility corridors.

VECTOR-P UAV PLATFORM

The Vector P (http://www.vectorp.com) is a small, low cost unmanned aerial vehicle (UAV) capable of remote control operation and/or fully autonomous flight. It is an all composite aircraft with a 2.6 meter wingspan powered by a 6 HP gasoline powered 2-cycle engine. The task of monitoring utility pipelines requires the UAV to fly slowly at low altitudes while still providing a stable platform for remote sensing. Typical utility monitoring missions are flown at an altitude of 200 meters with an airspeed of 60 knots.

The UAV is capable of carrying a 9 kilogram payload either housed internally in a 53 x 36 x 25 cm. payload bay or mounted externally to the fuselage undercarriage. The configuration used for corridor monitoring utilizes both payload options. The camera gimbal is mounted externally on the underside of the fuselage, while all of the electronics are located in the payload bay.

Figure 1. Vector P UAV

The UAV can be launched and recovered using a grass, dirt or asphalt runway. Required runway lengths vary from 100 to 300 meters depending on the load and the surface. Since corridor monitoring requires long flights and heavy fuel loadings, runway lengths of 300 meters are usually required. The UAV is launched and recovered using RC control. Once stable flight has been established, control is transferred to an on-board auto pilot. The auto pilot is preprogrammed with way points that trace the location of the utility corridor. The location of emergency recovery areas is also pre-programmed into the UAV in case certain emergency situations occur.

The way points as well as other autopilot functions can be altered in flight by using Mercury's VistaNAV ground control station (GCS) which maintains an low-cost, low-bandwidth connection to the UAV using a satellite communications (SATCOM) link. This capability is most often used when the on-board real-time processor detects an alarm in the right-of-way and the GCS operator decides another immediate look is required. The GCS then instructs the UAV to fly a circular pattern centered on the alarm's location and keeping the gimbaled camera aimed directly at that location.

CAMERA

The system utilizes a digital progressive scan color video camera that is interfaced to the on-board computer using an IEEE-1394 interface which is commonly referred to as "firewire". The on-board processing software splits the video stream into two components. The first component is compressed using software CODECS and then recorded on an on-board disk as a series of AVI files. The second component is sampled once every two seconds creating a full-resolution uncompressed image. That image is then passed to a separate process that identifies alarms by using anomaly detection methods.

The camera is housed in a gimbled assembly attached to the underside of the UAV fuselage. The gimble contains an integrated Global Positioning System/Inertial Measurement Unit system (GPS/IMU) and is stabilized using feedback logic that links the gimbal's servo-motors and the IMU under software control. Furthermore, the gimbal's integrated GPS can be used to determine the geographical location of the center of the video image.

REAL-TIME ANOMALY DETECTION

The on-board system uses proprietary anomaly detection algorithms to identify high-risk targets in the video image and to then raise an alarm to the operator at the GCS. This alarm is then supplemented by sending a highly compressed color image that shows both the entire video frame as well as the location of the anomaly. The anomaly detection utilizes both spectral and spatial methods as well as supervised and unsupervised classification techniques.

The alarm image is displayed on the GCS along with locational information derived from the on-board integrated GPS/IMU system. The GCS operator can then superimpose this image onto images captured on previous flights and then determine if the alarm poses an imminent danger. If necessary, the GCS operator can instruct the UAV to return to the target and capture additional imagery. An example of such an alarm is shown in Figure 2 below. This alarm image shows two cars that have been parked in the right-of-way. The anomaly detection software has detected the cars, marked them with black highlights and notified the GCS operator of the event.

Figure 2. Alarm Image

POST-PROCESSING CHANGE DETECTION

A typical corridor monitoring mission takes approximately four hours to fly. After the UAV has landed, the disk drive is removed and the digital AVI files are transferred to the GCS. The GCS incorporates a complete state-of-the-art aerial video processing system. A hardware accelerator board performs real-time video enhancement, fusion, stabilization and mosaicking. The system then places the processed video into a geospatial context so it can be directly compared with video taken during previous flights. Classical change detection algorithms are then used to identify video segments that a video analysts would then manually review.

COLLISION AVOIDANCE

Before UAV's can be used operationally to monitor utility corridors, it will be necessary to secure permission to do so from the Federal Aviation Administration (FAA). One requirement the FAA is certain to impose is a reliable method of collision avoidance. Experts and regulators expect that a “responsible” operator must remain in the UAV flight loop at all times to manage operations, control missions and handle emergencies that might result from system and communication failures. Work is currently underway to incorporate into the GDS three-dimensional (3D) visualization technologies that will improve the situational awareness of the GCS operator especially as it applies to collision avoidance.

CONCLUSIONS

The UAS system described in this paper promises to replace the use of manned aircraft and ground based vehicles for monitoring utility corridors for disturbances in an attempt to mitigate possible infrastructure damage. The UAS system can be operated for a fraction of the cost of manned systems while still providing real-time notification of suspect activities in the utility corridor.