Automated UAV-based Video Exploitation using Service Oriented Architecture Framework

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ABSTRACT

Airborne surveillance and reconnaissance are essential for successful military missions. Such capabilities are critical for troop protection, situational awareness, mission planning, damage assessment, and others. Unmanned Aerial Vehicles (UAVs) gather huge amounts of video data but it is extremely labour-intensive for operators to analyze hours and hours of received data.

At MDA, we have developed a suite of tools that can process the UAV video data automatically, including mosaicking, change detection and 3D reconstruction, which have been integrated within a standard GIS framework. In addition, the mosaicking and 3D reconstruction tools have also been integrated in a Service Oriented Architecture (SOA) framework.

The Visualization and Exploitation Workstation (VIEW) integrates 2D and 3D visualization, processing, and analysis capabilities developed for UAV video exploitation. Visualization capabilities are supported through a thick-client Graphical User Interface (GUI), which allows visualization of 2D imagery, video, and 3D models. The GUI interacts with the VIEW server, which provides video mosaicking and 3D reconstruction exploitation services through the SOA framework.

The SOA framework allows multiple users to perform video exploitation by running a GUI client on the operator's computer and invoking the video exploitation functionalities residing on the server. This allows the exploitation services to be upgraded easily and allows the intensive video processing to run on powerful workstations.

MDA provides UAV services to the Canadian and Australian forces in Afghanistan with the Heron, a Medium Altitude Long Endurance (MALE) UAV system. On-going flight operations service provides important intelligence, surveillance, and reconnaissance information to commanders and front-line soldiers.

Keywords: UAV, airborne reconnaissance, video exploitation, service oriented architecture, 3D reconstruction, mosaicking

1. INTRODUCTION

Airborne surveillance and reconnaissance are essential information for successful military missions. Such capabilities are critical for situational awareness, mapping and monitoring, and mission planning. Unmanned Aerial Vehicles (UAVs) are becoming the platform of choice for such operations since UAVs can fly in areas that are dangerous or contaminated, and can undertake dull, repetitive reconnaissance missions.

Video cameras are the most common UAV sensor payload as they are relatively inexpensive and light-weight. Video cameras can collect large amounts of data, however using this data efficiently and advantageously is a challenge. How the imagery is used depends on the mission goals and at which stage of the mission it is used. Data collected from UAVs must be reviewed quickly to support real-time operations in the field, whereas it is analyzed in more depth and over longer timeframes to support mission planning and intelligence gathering.

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In modern battlefields, there are significant data assets such as sensors, UAVs, satellites, ground vehicles, command and control systems, etc. [1] describes the use of Service Oriented Architecture (SOA) for persistent surveillance, as SOA brings heterogeneous network components under one framework. [2] proposes SOA as a means to integrate processing and data across organization which facilitates system-level integration, in the context of military capability.

At MDA, we have developed a suite of tools that can process video data automatically, including mosaicking, change detection and 3D reconstruction, under the Advanced Mapping from Imagery (AMI) project [1][4]. These tools have been integrated within a standard Geographic Information System (GIS) framework, offering a user-friendly interface to non-expert users. In addition, the mosaicking and 3D reconstruction tools have also been integrated in an SOA framework.

The Visualization and Exploitation Workstation (VIEW) integrates 2D and 3D visualization, processing, and analysis capabilities developed for UAV video exploitation. Visualization capabilities are supported through a thick-client Graphical User Interface (GUI), which allows visualization of 2D imagery, video and 3D models. The GUI interacts with the VIEW server, which provides video mosaicking and 3D reconstruction exploitation services through an SOA.

The SOA framework allows multiple users to perform video exploitation by running a GUI client on the operator's computer and invoking the video exploitation functionalities residing on the server. Therefore, the client computer does not need to install a copy of the video exploitation tools. Moreover, this allows the exploitation services to be upgraded easily and allows the intensive video processing to run on powerful servers. Furthermore, this allows exploitation capability developed on a wide range of platforms to be integrated and exposed as services through a common interface.

This paper gives an overview on video exploitation tools developed at MDA and the SOA framework. Section 2 will review the video exploitation tools developed under the AMI project. The SOA framework will be presented in Section 3 while Section 4 will describe the visualization client. Experimental results will be shown in Section 5.

2. VIDEO EXPLOITATION TOOLS

The AMI tools have been implemented as extensions of ESRI ArcGIS, which is a family of products for visualizing, managing, creating, and analyzing 2D and 3D geographic data. ArcGIS is being used within the Canadian Forces Directorate of Geospatial Intelligence. Therefore, developing on the ArcGIS platform minimizes the learning curve for these end-users and ensures these tools would fit into their current work process. While the AMI GUI is built within ArcGIS, the underlying tools are not dependent on ArcGIS and could be integrated into any other selected environment.

Visualization is a key component of AMI, as it allows the operator to view videos, see the UAV path and the extent of the video footprint on a map. The operator can then select region of interests (ROI) and create exploitation products. The ROI selection is important as it allows processing on selected regions, which can greatly reduce processing time, especially when not all the imaged area is of interest. Figure 1 (left) shows the AMI GUI front-end, which plays videos and displays UAV paths and video footprints on the map using the information directly supplied in the video meta-data (GPS/INS). The user can select an ROI on the map to focus the processing on that region.

2.1 Mosaicking

Individual video frames in a video sequence provide only a narrow view of a scene. Even if the user views the entire video data set by playing the video from start to end, the user needs to rely on memory of the scene content, to form a mental picture of the area that was surveyed by the sensor. Thus, it is very difficult to obtain situational awareness from video data. The mosaicking tool helps to solve this problem by producing a high-resolution 2D geo-referenced image from the sequence of video frames contained in a video clip, effectively showing the information from all the frames simultaneously, and thus providing better geographical situational awareness.

The mosaicking tool offers both quick-look and refined mosaicking options. For the quick-look mosaic, the video frames are stitched together based on the un-calibrated video meta-data only. For the refined mosaic, the video meta-data is first improved by calibration, after which the video frames are aligned and blended into a seamless mosaic. Figure 1 (right) shows an example of a geo-referenced refined mosaic generated from an infra-red (IR) video, overlaid on top of a reference map to provide a high resolution up-to-date 2D image to the operator.

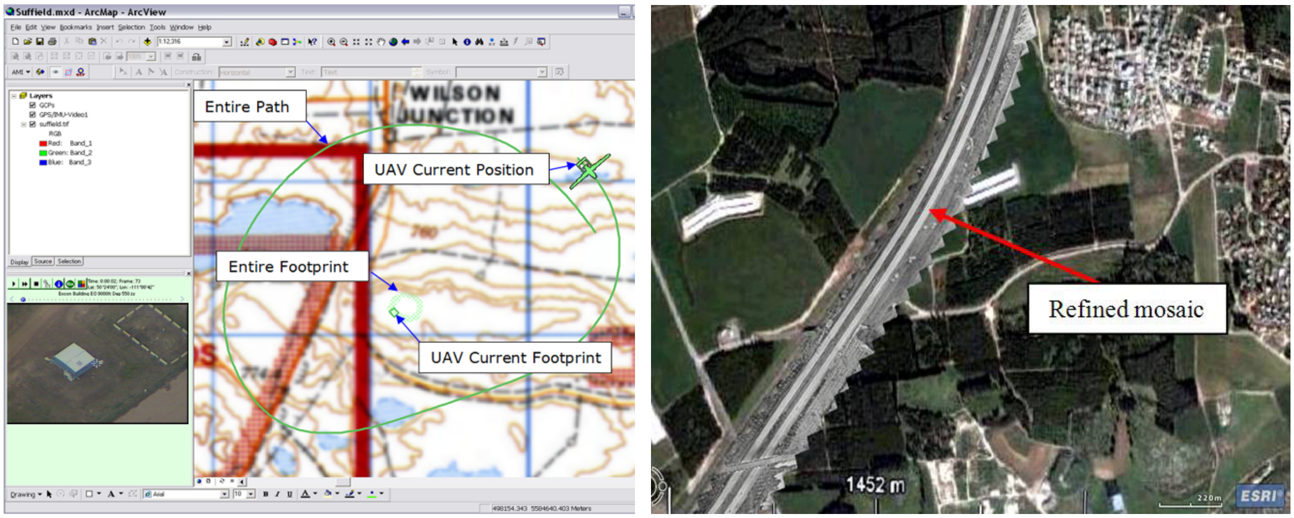

Figure 1 AMI UAV Video Player and Meta-data Display (left) and Refined Mosaic Overlaid on Background Map (right)

2.2 Change Detection

For scene monitoring applications it is important to be able to identify changes and anomalies. However, it is tedious and difficult for humans to compare hours of video clips looking for differences. The change detection tool automatically finds differences between two videos taken from two passes of the same terrain at different times. Changes between the two video files are identified and flagged on the video frames, so that operator attention can be utilized more effectively by focusing only on the detected changes.

The change detection tool offers a suite of filters to control the type of changes to detect, in order to both avoid overwhelming the operator with too many changes and to help the operator hone in to the attributes of the changes that are significant for that scene. For example, the operator can control the intensity or area thresholds of the changes to be detected. Figure 2 (left) shows the change detection tool, where two IR videos with the detected changes are displayed. The change highlighted by the red circle corresponds to an unknown object on a road: it is observed in the first video, but not in the second video.

2.3 3D Reconstruction

For situational awareness, it is easier to understand the scene by visualizing it in 3D. The 3D reconstruction tool can generate 3D models automatically, provided that the video frames contain sufficient texture. It creates calibrated geo-referenced photo-realistic 3D models, which can be viewed with common 3D GIS viewers. The models can be viewed from different perspectives, and allow distance measurements and line-of-sight analysis.

The 3D reconstruction tool processes the input frames in a pair-wise fashion and generates geo-referenced textured 3D meshes in KML format. The tool can handle both optical and IR data, which is valuable for night-time operations. Figure 2 (right) shows the photo-realistic 3D model generated from an IR video that was captured while the UAV flew around a building of interest.

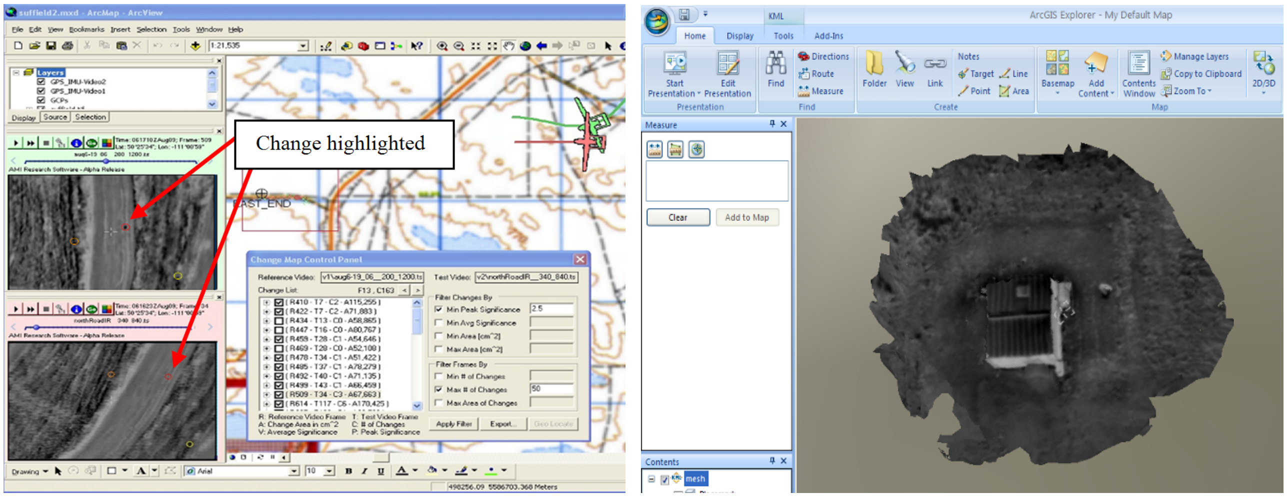

Figure 2 Change Detection Tool (left) and Infra-red 3D Model Generated by 3D Reconstruction Tool (right)

3. VIEW OVERVIEW

Figure 3 shows the conceptual architecture for VIEW. Visualization capabilities are supported by VIEW through a thick-client Graphical User Interface (GUI). The GUI allows visualization of 2D imagery, video, and 3D models and their associated information. It also allows the operator to invoke exploitation functions on the data.

The GUI interacts with the VIEW framework, which provides data and exploitation services to the GUI through an SOA. Data services are implemented in the VIEW framework through access to a Storage Layer, where data and meta-data are stored. Exploitation services are implemented either within the VIEW framework, or through integration with external exploitation technologies.

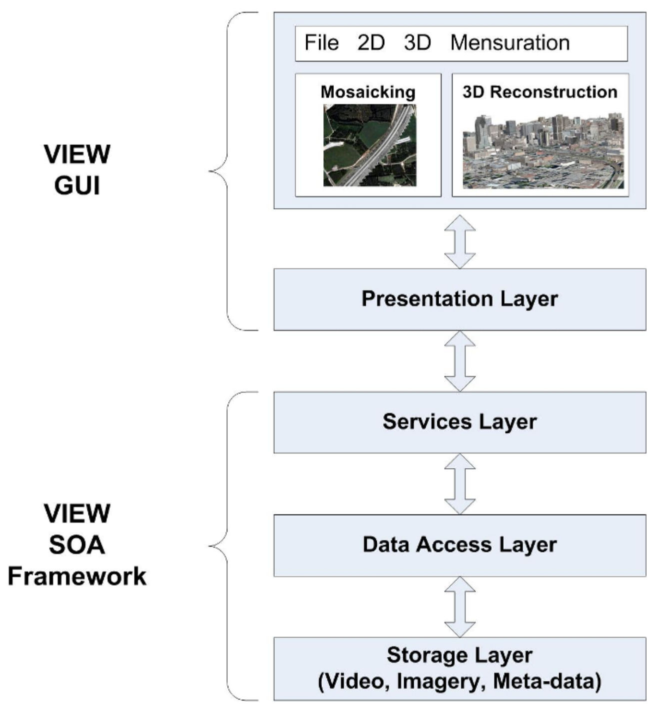

Figure 3 VIEW Conceptual Architecture

The VIEW SOA framework provides the basis for

- Integrating non-SOA applications into an SOA framework
- Exposing visualization and exploitation services to the VIEW client GUI or other SOA clients
- Invoking external services from the framework

VIEW comprises two separate functional components that expose and interact through web services: the Content Repository to manage content (video, images, etc) and the Exploitation Application Server to provide video exploitation services. These components as well as the interface and available services will be described further below.

3.1 Content Repository

The Content Repository is designed as a simple storage capability to support the exploitation services. The Content Repository follows the World Wide Web Consortium (W3C) standards by associating a Universal Resource Locator (URL) to each file stored in the repository. The URL is the external handle to the file (resource) and hides the internal implementation of the file storage. Similar to the web, any client can use an HTTP GET on the URL to retrieve the content of the file. The Content Repository supports a hierarchical folders structure, with folders containing files or other folders.

3.2 Exploitation Application Server

The Exploitation Application Server integrates existing video exploitation capabilities and exposes them as web services. The mosaicking and 3D reconstruction tools have been integrated. The Exploitation Application Server retrieves and stores files in the Content Repository. It implements asynchronous service calls for these non-real-time exploitation services and it invokes external executables to perform the actual video exploitation service.

3.3 External Interface

The VIEW framework exposes web services and incorporates web services standards such as HTTP, SOAP (Simple Object Access Protocol), WSDL (Web Service Definition Language). Exploitation service requests will reference files already stored in the VIEW framework using unique URLs. The exploitation service results will return URLs of newly created files which have been stored in the VIEW framework as a result of running the exploitation service.

The majority of the VIEW framework web services are implemented using SOAP over the HTTP transport using the document/literal binding. This means that the HTTP request and response both carry a SOAP document, the body of which contains an XML message. In the event of an error, the HTTP response carries a SOAP Fault, indicating the error. All SOAP/HTTP web services are defined using WSDL Version 1.1 files.

3.4 VIEW Services

The VIEW framework implements both synchronous and asynchronous services. Synchronous services return their result directly to the client, while asynchronous services return their result at a later time.

Synchronous SOAP/HTTP services return the service results directly in the HTTP response for the HTTP service request. The following synchronous SOAP/HTTP services are supported:

- listFiles: List all folders and files in the Content Repository
- getFile: Retrieve a file in the Content Repository, identified by its unique URL
- deleteFile: Delete a file in the Content Repository, identified by its unique URL
- fetchResult: Fetch the result of a previous asynchronous service, using the *requestId* returned by the service
- ping: Check whether the VIEW framework is running

The VIEW exploitation services could take tens of seconds to execute. To avoid blocking the service client, these services are implemented asynchronously, using client polling to retrieve the service results. The following asynchronous services are supported:

- Mosaicking: Generate a geo-referenced mosaic from a video file and return *requestId* which can be used to pick up the result
- 3D reconstruction: Generate a geo-referenced photo-realistic 3D model from a video file and return *requestId* which can be used to pick up the result

4. VISUALIZATION CLIENT

Various existing open-source or Commercial Off-the-Shelf (COTS) 3D GIS viewers were evaluated for their suitability as the VIEW visualization client. The following criteria are used for the evaluation.

- Integrated 2D/3D GIS viewing support
- Basic format support such as GeoTIFF, KML, shapefiles
- Free or as close as possible
- Good performance with smooth navigation
- Customizable displays and interface
- Good SDK (Software Development Kit) or API (Application Programming Interface) and support

The evaluation included the following commonly used 3D GIS viewers:

- Google Earth Pro [6] is a virtual globe, map and geographical information viewer which is widely used and considered the industry benchmark for 3D GIS visualization. Offering more features, the Pro version is for commercial use and charges an annual subscription fee per user.
- ESRI ArcGIS Explorer [7] is a free application that offers an easy way to access online and offline GIS data and capabilities. It provides access to a wide selection of ready-to-use datasets hosted by ESRI, which can be combined with local data or other services to create custom maps and perform spatial analysis.
- NASA World Wind [8] is a free open-source virtual globe that lets you zoom from satellite altitude into any place on Earth, leveraging Landsat satellite imagery and Shutter Radar Topography Mission data.
- Microsoft Virtual Earth [9], recently rebranded as Bing Maps, is an integrated set of services that provides quality geospatial data, rich imagery for visualization.
- Delta3D [10] is an open-source 3D simulation engine commonly used in gaming. It has strong 3D modeling capabilities but does not include a base model of the Earth.
- GeoTime [11] is a product for the concurrent visualization of geospatial and temporal data. Events are animated in time through the 3D space as the time slider bar is moved.

Based on a combination of performance, functionality, pricing and API/SDK consideration, ArcGIS Explorer is chosen as the VIEW visualization client. ArcGIS Explorer supports a wide range of 2D and 3D formats, including GeoTIFF, 3D KML, shapefiles, etc. It is freely available and is being maintained by ESRI regularly, e.g. Version 1200 released in March 2010 and Version 1500 released in August 2010. While it is not possible to develop stand-alone tools using their API, SDK is available to add customized tools, and is well-supported by ESRI. The 3D visualization does not perform as smoothly as Google Earth on modest hardware, but the performance improves with better 3D graphics card and more computer memory.

5. PROTOTYPE DEVELOPMENT

The VIEW server and client prototype system has been developed, as illustrated in Figure 4. The VIEW SOA server, residing on a high-performance computer, has been implemented in Java using Enterprise Services Bus (ESB) as the integration framework. It integrates various free open-source components including Mule ESB [12], Apache ActiveMQ [13], Apache CXF [14] and jBPM [15]. C++ executables for the video exploitation services also reside on the VIEW server computer. It is assumed that the video datasets have been calibrated and reside in the Content Repository on the VIEW server.

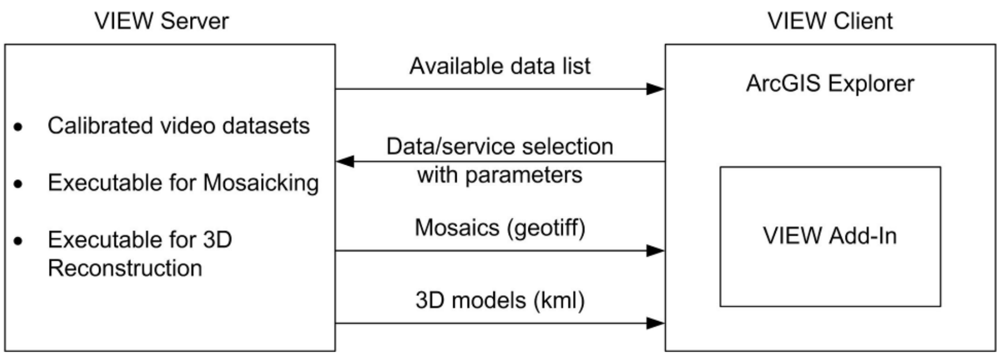

Figure 4 The VIEW Server and Client Prototype System

For the VIEW visualization client, an add-in has been implemented using C# .NET for ArcGIS Explorer Version 1200. By building upon an existing 3D GIS viewer, the operator can make use of the extensive GIS capabilities provided by ArcGIS Explorer, including a large selection of background maps, measurements and annotation functionalities, etc. The VIEW client runs on the operator's computer and connects to the VIEW server computer via network/internet. The user can select video datasets residing on the VIEW server to process. The VIEW client GUI is shown in Figure 5 and provides the following VIEW-specific functionalities:

- Content browser allows users to query and get a list of available data.
- Mosaicking interface allows users to configure the options and invoke the mosaicking service.
- 3D reconstruction interface allows users to configure the parameters and invoke the 3D reconstruction service.

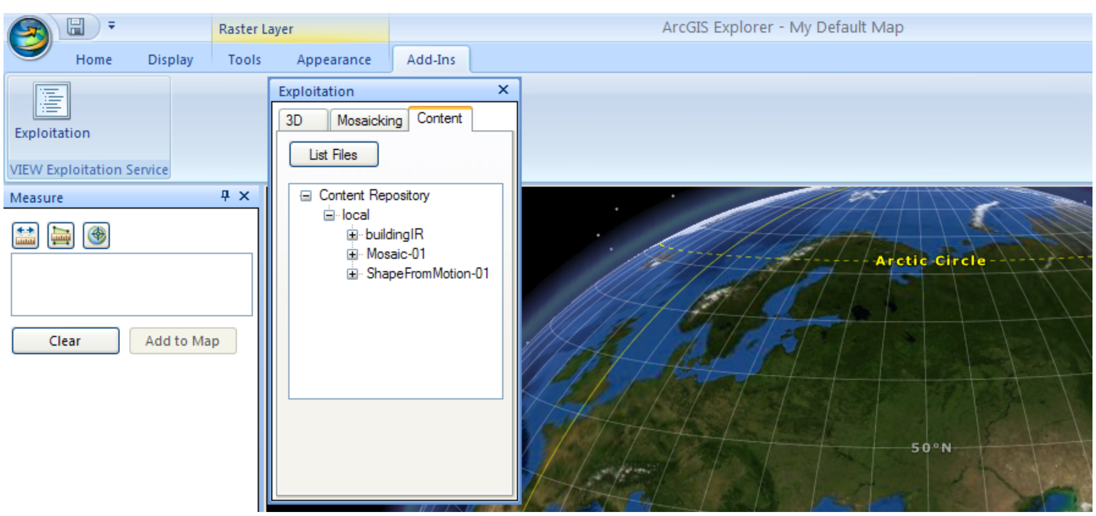

Figure 5 VIEW Client GUI based on ArcGIS Explorer

The typical sequence of events is as follows:

1. The VIEW client requests for a list of files and folders in the Content Repository on the VIEW server.
2. The VIEW client sends the selected service and dataset, together with any service-specific parameters to the VIEW server.
3. The VIEW server starts running the selected video processing on the chosen dataset.
4. The VIEW client checks periodically until the processing has been completed, which takes around a minute for the test datasets.
5. The VIEW client displays the resulting geo-referenced mosaic (geotiff) or photo-realistic 3D model (kml) over its background map, as shown in Figure 6.

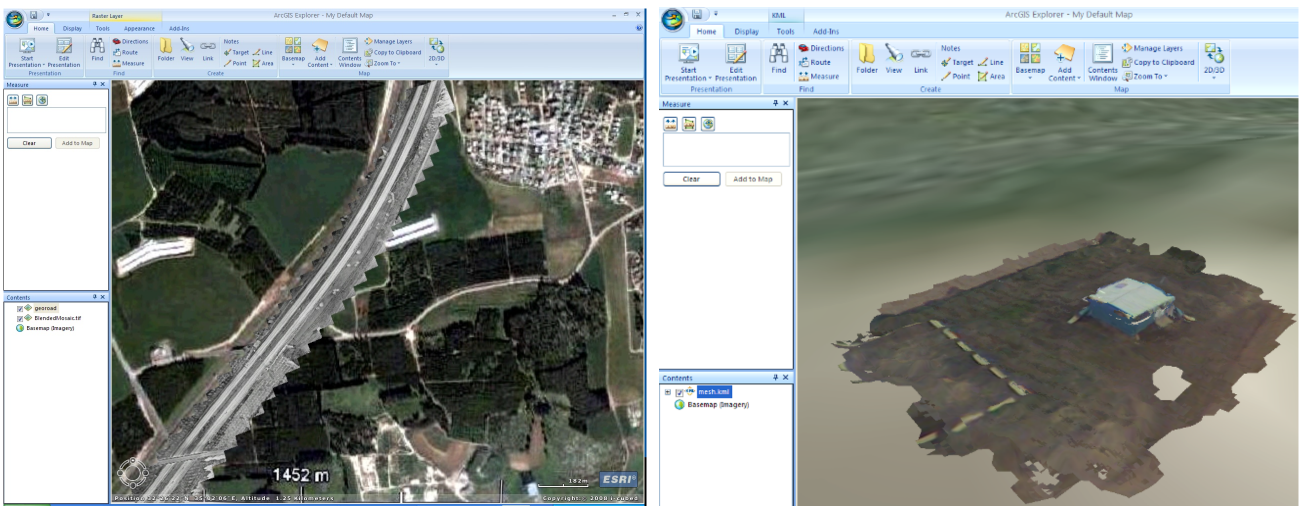

Figure 6 Resulting Mosaic (left) and Photo-realistic 3D Model (right) in VIEW Client GUI

6. CONCLUSIONS

MDA has been providing UAV services to the Canadian and Australian forces in Afghanistan with the Heron, a Medium Altitude Long Endurance (MALE) UAV system [16]. The on-going flight operations service provides important intelligence, surveillance and reconnaissance information to commanders and front-line soldiers. UAVs gather huge amounts of video data, but it is extremely labour-intensive for operators to analyze such data. Our suite of fully automated video exploitation tools can aid operators in analyzing the large amounts of UAV video data collected to support battle-space mapping and monitoring applications.

MDA has developed a suite of UAV video exploitation tools that have been integrated into ArcGIS to demonstrate a user-friendly tool-set that complements the GIS functionality provided by ArcGIS. Test results show that these video exploitation products are generated successfully from Heron UAV video data. The beta version of the tools has been delivered to the Canadian Forces Directorate of Geospatial Intelligence for evaluation.

The Visualization and Exploitation Workstation (VIEW) integrates 2D and 3D visualization, processing, and analysis capabilities developed for UAV video exploitation. Visualization capabilities are supported through a client GUI based on the ArcGIS Explorer, which allows visualization of 2D imagery, video and 3D models. The GUI interacts with the VIEW server, which provides video mosaicking and 3D reconstruction exploitation services through an SOA.

The SOA framework allows multiple users to perform video exploitation by running a client GUI on the operator's computer and invoking the video exploitation functionalities residing on the server. Therefore, the client computer does not need to install a copy of the video exploitation tools. This allows the exploitation services to be upgraded easily and allows the intensive video processing to run on powerful workstations or servers. Moreover, various exploitation capabilities can be integrated and exposed as services through a common interface. Future work includes improving the performance of the services and integrating more exploitation services in the VIEW SOA server.

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REFERENCES

[1] G. Chen, D. Shen, E. Blasch, K. Pham, H. Chen, Services oriented architecture (SOA)-based persistent ISR simulation system, *Proceedings of SPIE Vol. 7694*, Orlando, Florida, April 2010.
[2] D. Russell, N. Looker, L. Liu, J. Xu, Service-oriented integration of systems for military capability, *Proceedings of 11th IEEE Symposium on Object Oriented Real-Time Distributed Computing (ISORC)*, Orlando, Florida, May 2008.
[3] S. Se, P. Firoozfam, N. Goldstein, L. Wu, M. Dutkiewicz, P. Pace, JPL Naud, Automated UAV-based mapping for airborne reconnaissance and video exploitation, *Proceedings of SPIE Vol. 7307*, Orlando, Florida, April 2009.
[4] S. Se, P. Firoozfam, N. Goldstein, M. Dutkiewicz, P. Pace, Automated UAV-based video exploitation for mapping and surveillance, *Proceedings of International Society for Photogrammetry and Remote Sensing (ISPRS) Commission I Symposium*, Calgary, June 2010.
[5] ESRI ArcGIS, http://www.esri.com
[6] Google Earth Pro, http://www.google.com/enterprise/earthmaps/earth_pro.html
[7] ESRI ArcGIS Explorer, http://www.esri.com/software/arcgis/explorer/index.html
[8] NASA World Wind, http://worldwind.arc.nasa.gov/java/
[9] Microsoft Virtual Earth, http://www.microsoft.com/bi/products/virtual-earth.aspx
[10] Delta3D, http://www.delta3d.org/
[11] GeoTime, http://www.oculusinfo.com/SoftwareProducts/GeoTime.html
[12] Mule ESB, http://www.mulesoft.org/
[13] Apache ActiveMQ, http://activemq.apache.org/
[14] Apache CXF, http://cxf.apache.org/
[15] jBPM, http://www.jboss.org/jbpm
[16] MDA Unmanned Systems, http://www.uavs.ca/