HOW CAN AIRBORNE VIDEO PROVIDE HIGH RESOLUTION GEO-REFERENCED IMAGES IN REAL-TIME FOR FOREST FIREFIGHTERS USING WEB SERVICES

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ABSTRACT:

In the framework of the European FP6-IST OSIRIS project a web architecture allowing multiple sensors "plug and play" capacity for disaster management have been designed and implemented. The functionalities of the system have to be demonstrated through four main live demonstrations, one of them focusing on forest fire. A small controlled fire has been initiated by the French fire brigades. Four sensor types were deployed : personal positioning systems for firemen, smart wireless video/IR ground cameras, a mobile meteorological station and an airborne remote sensing system providing real-time video imagery. After data processing and data merging the generated information was available via web services.
This paper focuses on the remote sensing system part. The video images and the GPS data were directly transmitted from the airplane to the ground receiving station (located on site) for synchronization and archiving. The data were then transferred to the VITO premises (Belgium) via a robust point-to-point satellite communication system. High resolution geo-referenced images of the area were automatically generated at regular time intervals using a high-performance computing (HPC) cluster. The results were available via WMS and CWS web services and could be easily visualized using standard applications like Google Earth. This allows to perform continuous and up-to-date assessment of the situation simultaneously from different locations.
The complete remote sensing system (including the communication system) was developed in a flexible way allowing further use with different types of platforms and EO sensors.

RÉSUMÉ:

Dans le cadre du projet européen FP6-IST OSIRIS une architecture de type web à été développée afin de permettre l'insertion facile de systèmes de capteurs utilisés pour la gestion de crises. Les différentes fonctions du système ont été démontrées au travers de 4 démonstrations effectuées en temps réel, l'une d'entres elles concernant la problématique des feux de forêts. Un "petit" feux contrôlé à été initié par les sapeurs pompiers français dans le cadre d'écobuages. Quatre types de capteurs furent déployés : un système de positionnement personnel pour les sapeurs pompiers, un réseau de caméras « intelligentes » de types vidéo et infrarouge, une station météorologique mobile ainsi qu'un système de télédétection aéroporté délivrant des images vidéo en temps réel. Après traitement et fusions des différentes données l'information générée fut mise à disposition des utilisateurs via des services de type web.
Cet article décrit le système aéroport utilise ainsi que les résultats obtenus lors de la démonstration. Les images vidéo ainsi que les données GPS furent directement transmises de l'avion au sol (sur site) afin de synchroniser celles-ci et de sauvegarder les données brutes. Après compression ces données furent directement transmisses au VITO (Belgique) au moyen d'un système robuste mobile de communication satellitaire. Les images haute résolution géo-référencées de la zone survolée furent produites automatiquement à intervalles régulier grâce au réseau d'ordinateur puissants travaillant en groupe (cluster). Les produits générés furent disponible via des services web de type WMS et CWS afin de pouvoir être directement utilisés dans des applications telles que Google Earth. L'utilisation de services de type web permet d'évaluer de façon continue l'évolution de la situation à partir de locations différentes.

1. INTRODUCTION

In 2002 the Flemish Institute for Technological Research (VITO) started the Pegasus project (Pegasus, 2009) to examine the feasibility of a stratospheric solar driven Unmanned Aerial Vehicle (UAV) as a platform for very high resolution remote sensing for cartographic applications. The complete system is composed of four main parts (Figure 1) : the Mercator long endurance UAV, a high resolution light weight digital RGB camera called MEDUSA (Medusa, 2009), a mobile ground control station for the reception and archiving of the telemetry and of the raw payload data and a powerful Central Data Processing Center (CDPC) located at the VITO premises in Mol-Belgium (Biesemans *et al.*, 2007).

In the framework of the European FP-6 OSIRIS project (Osiris, 2009) it was proposed to use the Pegasus system to provide in near real-time high resolution images to the command post of the fire brigades during a live demonstration focusing on forest fires. The end products generated by the Pegasus system had to be accessible using OGC (Open Geospatial Consortium) compatible web services in order to allow to access the information from different locations and in-situ sensor systems at the same time if required. The possible re-routing in near real-time of the UAV itself on request of the fire brigades via a sensor planning web service (SPS) had also to be developed using a simple web interface. Finally the proposed solution had to be autonomous (working far from any infrastructure), flexible (allowing the plug-in of other sensor system types), mobile and easily deployable (in order to simulate operational conditions).

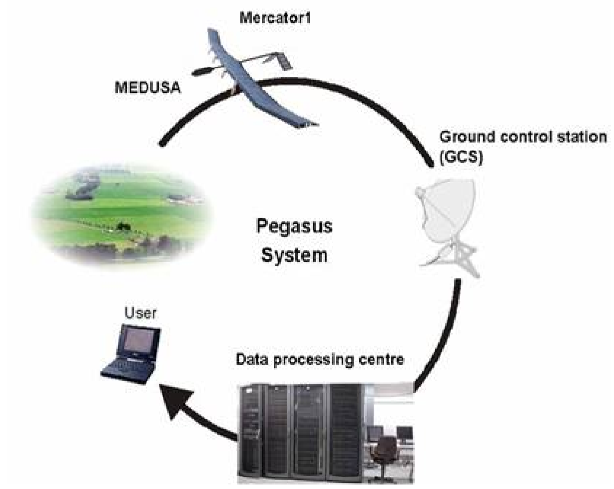

Figure 1: Schematic view of the Pegasus System

2. THE OSIRIS PROJECT

The OSIRIS project "Open architecture for Smart and Interoperable networks in Risk management based on In-situ Sensors" aims at connecting in-situ sensors via an intelligent and versatile architecture that allows end-users to access multi-domain sensors information in real-time (Osiris, 2009). The architecture is generic and allows to plug-in different type of in-situ sensors (when Sensor Web Enablement - SWE compatible) on an easy way.

The functionalities of the OSIRIS architecture that is based on OGC (Open Geospatial Consortium, Inc. ®) standards has been demonstrated during four live demonstrations dealing respectively with fire in industrial buildings (in Aachen-Germany), water pollution (Regione Toscana in Italy), air pollution in urban areas (city of Valliadolid in Spain) and forest fires (in the department du Gard located in the South of France).

In the framework of the forest fires live demonstration four types of sensors has been used, all accessible in real-time via SWE (Sensor Web Enablement) services. The deployed sensors were: a network of in-situ wireless smart imaging sensors (video and IR cameras), a network of in-situ personal positioning sensors combining GPS and Ultra Wide Band (UWB) systems, a mobile meteorological weather station to provide accurate local meteorological information and an Airborne Remote Sensing (ARS) system to generate at regular intervals high resolution RGB images.

3. THE AIRBORNE REMOTE SENSING (ARS) SYSTEM DEPLOYED DURING THE OSIRIS FOREST FIRE DEMONSTRATION

Due to clearance issues (authorization to fly) the Mercator-Medusa system had to be replaced by a manned airplane equipped with video camera providing "similar" type of spatial and spectral information. The airplane was a Cessna 208B Gran Caravan (able to fly continuously up to 6-8 hours, simulating to some extend a long endurance capacity) equipped with a Wescam MX-15 camera providing visible and IR videos. For this demonstration, only the "visible" video was used.

The spatial resolution was fixed to 30 cm GSD in order to simulate at best the Medusa data. The camera was fixed nadir looking (despite the system instability when approaching the vertical position).

The UAV Ground Control Station initially foreseen was replaced by a small mobile Processing and Archiving Facility (µ-PAF) for preliminary pre-processing and for archiving of the data coming from the Wescam camera.

In order to fulfil the requirement of being autonomous, the Pegasus system was customized by adding a robust mobile high data rate two-way satellite communication system between the operation site and the Central Data Processing Center (CDPC) located in Belgium. Once pre-processed and archived on site, the data were thus send to Belgium for further processing. Despite the delay caused by the satellite communication, the end-products were available in near real-time (few minutes delay) via web services.

Figure 2 shows the overall view of the complete ARS system as deployed during the live forest fire demonstration.

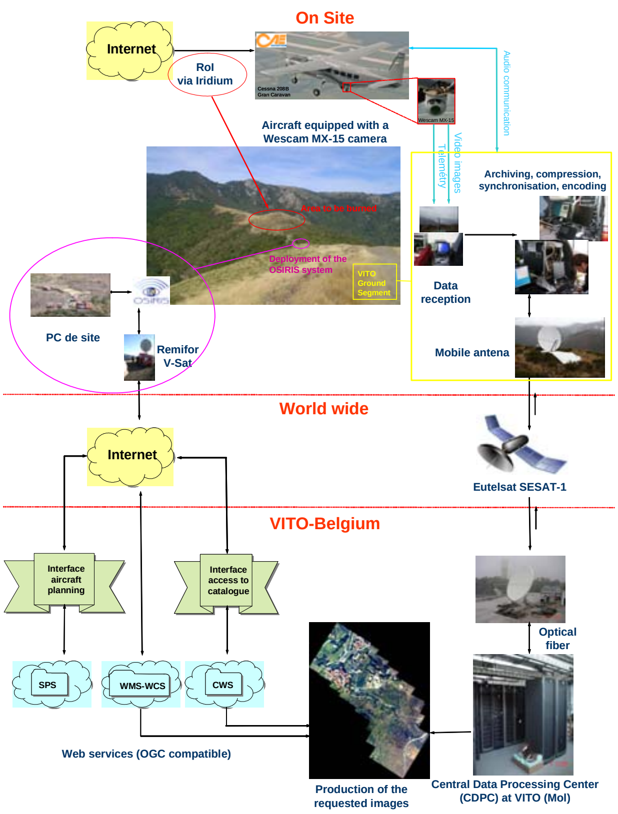

Figure 2: Schematic view of the complete ARS system

4. THE LIVE DEMONSTRATION

The forest fire demonstration was composed of a two day experiment: the first day being a general repetition, the second consisting of the live demo for the end-users and stakeholders.

The location for the demonstration has been chosen by the fire brigade of SDIS 30 (Gard) and was situated close to the "Col du Vilaret" near Le Vigan.
Originally the complete top of a small hill (radius of ~ 150 m) covered by very flammable vegetation type (Genêts purgatifs – *Cutisus purgans*) has to be burned (Figure 3).

Figure 3: Picture of the demonstration site

However, due to very strong winds encountered the day of the demonstration the final extension of the fire was limited to an area of approximately 15 * 30 square meters. Straw was used (see yellow area on Figure 4) to obtain a real fire as the vegetation was too wet due to the very strong rain encountered the day before the demo.

Figure 4: Picture of part of the fire brigade deployment on site

The bad meteorological conditions also affected the deployment of the ARS system itself during the demonstration: the winds detain the deployment of the mobile satellite antenna while the important cloud coverage affected strongly the quality of the images during the fire. Therefore all functionalities could not be fully demonstrated during the demonstration day. The results described here below are thus a synthesis of the two-day experience (general repetition + demonstration day).

During the operation, both the video stream and some telemetry (GPS position and GPS time) was sent in real time to the "on-site" ground segment. The video was transmitted using COFDM modulation (2.3-2.5 GHz band) while the telemetry was sent using the UHF band. The data were directly forwarded to the µ-PAF for archiving and for synchronisation of the two data sets (video and GPS). A Genlock system was also used in order to maintain a continuous video frame rate, especially when the aircraft was turning, covering thereby the emitting antenna (which results in a loss of signal at the ground level).

Once synchronized, the video stream was split in a sequence of shorter video streams, each covering 15 seconds of acquisition. The data were afterwards compressed and encoded before transfer to the VITO-CDPC (in Belgium) via the point-to-point satellite communication system (using the Eutelsat SESAT-1 satellite).

After reception at the VITO premises, the data were first decoded and decompressed. The 15 seconds video streams were then processed in order to generate a stitched image (an image resulting of the pixel-based composition of several adjacent images extracted from the video stream). The images were subsequently geo-referenced using the GPS position and time.

Some of the stitched images were subsequently combined in order to generate a larger mosaic. All data were afterwards archived and accessible in near real-time through a Web Catalogue Service (WCS) using WMS (Web Map Service) and WCS (Web Coverage Service) services.

A Sensor Planning System (SPS) service coupled to an Iridium satellite communication system was also available in order to request in real-time changes in the flying pattern of the aircraft via simple SMS message.

5. RESULTS

The on-site data reception and synchronization as well as the transfer of the data to the VITO premises was successfully performed in real-time (however with some few delay because of the satellite communication system). A satellite link performance index (Eb/N0) between 9 and 10dB was always achieved despite the sub optimal weather conditions (strong rain during the general repetition) as can be seen on Figure 5.

Figure 5: Picture taken during the test performed for the satellite data transfer

At the VITO level the data were successfully received, archived and processed. Access via WMS and CWS services was insured in near real-time.

Figure 6 shows an example of a stitched image generated from a 15 seconds video sequence.

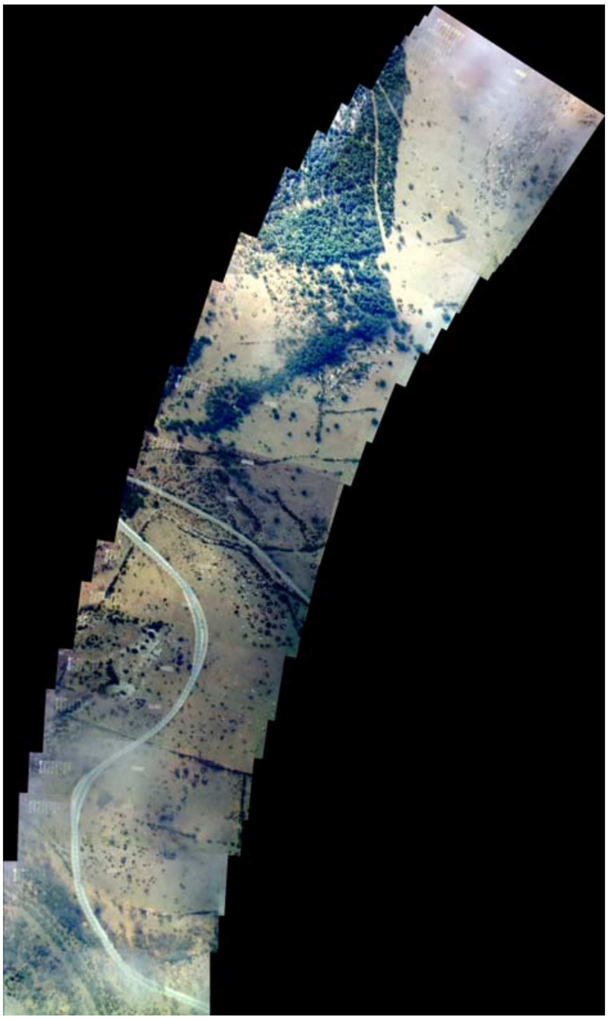

Figure 6: Example of stitched images produced from a short video sequence

The geo-referenced images could afterwards be visualized using common GIS tools. Figure 7 shows two composite images taken above the demonstration site that has been inserted in the Google Earth © application for visualization purpose. Zooming on these images delivers a higher level of detail as shown on Figure 8 where the trucks of the fire brigade (red and yellow) can be located as well as the area covered with straw (larger yellow area in the middle of the picture).

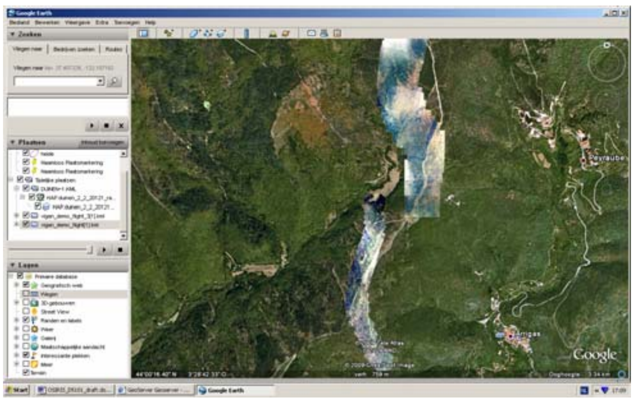

Figure 7: Example of stitched images of the demonstration area inserted in the Google Earth application

Figure 8 : Zoom performed on one of the two stitched image (upper one) presented in Figure 6.

The mosaic products are created using image stitching, which is the sequential coregistration of the video-frames using the first frame of a sequence as reference. Registration of two or more images comes down to finding the transformation (translation, rotation and scale parameters) that makes them align best. As such, coregistration is not an orthorectification and the resulting cartographic accuracy is not optimal. Currently under development at VITO, is to replace the stitching process of a video sequence by a combined block bundle adjustment and orthorectification process, this to achieve a better planimetric accuracy in mountainous regions.

Despite these planimetric accuracy issues, the positioning of the generated stitched images onto the reference images was quite successful and the level of accuracy obtained certainly sufficient as compared to the requirements of the application (forest fire).

Finally, using the OSIRIS client application developed by the French private company Thales (prime of the project and partner in the demonstration) one could combine the information provided by the stitched images and the other sensors. Figure 9 shows the different layers for the mobile positioning units, the position of the videos/IR cameras as well as the position of the meteorological mast, all superposed with the stitched image generated and a high resolution image of the site used as background.

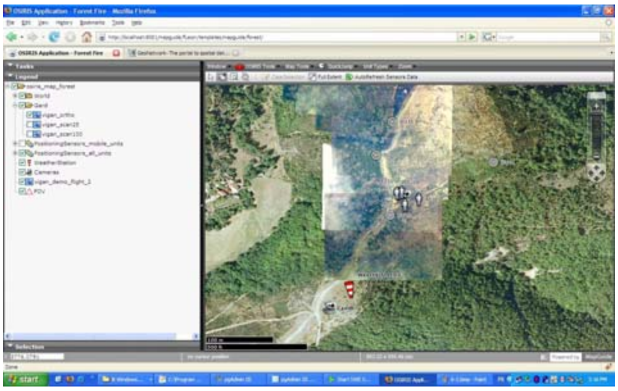

Figure 9: Result of combining the information provided by the different sensors involved in the forest fire demonstration.

6. CONCLUSIONS AND OUTLOOK

Despite the constraints encountered during the live demonstration (bad meteorological conditions, not using a UAV,..) all steps of the ARS system have been successfully demonstrated during this 2-day experience: acquisition, synchronization, archiving, compression, encoding, transmission, stitching, geo-referencing, mosaic generation and availability of the geo-referenced mosaics through web services.

The planimetric accuracy of the mosaics was sufficient for the application targeted. A higher spatial accuracy would require the use of block bundle adjustment combined with an orthorectification instead of the simple and fast coregistration.

The real-time aspect, possible thanks to the full automatic processing chain, although quite challenging was successfully achieved.

The use of standard services (e.g. SWE) allows easy data fusion (with results obtained from other sensors) in a format directly usable in standard GIS systems.

The demonstration also proved that a simple video stream combined to GPS data can be very useful to end-users.

The whole system was developed with special emphasize on two key-words: mobility and flexibility. The processing chain developed for cluster computing is sensor generic and the final products are independent of the acquisition system: it can be adapted to other type of imaging systems (other camera and/or platform types).

Considering the continuous development performed concerning UAVs (low, medium and high altitude) the potential of this technology (video + GPS data) in support to crisis and disaster management seems promising. Some private companies operating a.o. for the fire brigades and/or the police have already expressed their interest in the type of products as generated with the ARS system in the framework of the OSIRIS project.

7. REFERENCES

Pegasus, 2009. http://www.pegasus4europe.com (accessed on 5/11/09)

Medusa, 2009. http://medusa.vgt.vito.be (accessed on 5/11/09)

Biesemans J., Sterckx S., Knaeps E., Vreys K., Adriaensen S., Hooyberghs J. and Deronde B., 2007. Image processing workflows for airborne remote sensing. In: *Proceedings 5th EARSeL SIG IS Workshop*, Bruges, Belgium, edited by I. Reusen

Osiris, 2009. Open architecture for Smart and Interoperable networks in Risk management based on In-situ Sensors. http://www.osiris-fp6.eu (accessed on 05/11/09)

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