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Reviews

Airborne Video as a Remote Sensor for Linear Target: Academic Research and Field Practices

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선형지상물체에 대한 원격센서로서의 항공비디오: 연구추세 및 실무에서 사용현황

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Abstract : An important aspect of remote sensing research would be ultimately the production of research output so that operational people can directly use it. However, for the strip target, it is not certain how the research output in remote sensing helps the field user in adopting and utilizing the technology successfully. The relative limitation of traditional remote sensing systems for such a linear application is briefly discussed and the strength of videography are highlighted. Based on the postulated advantages of video as corridor sensor, a careful and extensive investigation has been made of research trends for airborne videography to identify how past research matches to demand of field clients. It is found that while video has been operationally used for strip target in field client communities, much research effort has been directed to area target, and relatively little towards the classification and monitoring of linear target. From this critical review, a very important step has been made concerning the practicality of airborne videography. The value of this paper is warranted in proposing a new concept of video strip monitoring(VSM) as future research direction in recognition of sensor characteristics and limitations. Ultimately, the suggestion in this paper will greatly contribute to opening new possibilities for implementing VSM, proposed as an initial aim of this paper.

Key Words : video strip montoring, operational remote sensing

요 약 : 원격탐사관련 학문적인 연구에서 중시해야 할 측면은 실제 현장에서 고객들이 직접 그 연구결과를 어느 정도 활용할 수 있는 지에 있다. 전통적인 원격탐사센서가 선형지상물체를 감지하는 능력에서 근본적인 한계점을 감안한다면 이와 같은 기술을 이용한 연구가 어느 정도 현장의 고객들이 원격탐사를 도입 활용하는 데 도움을 주었는지가 상당히 의문시된다. 이와 같은 문제에 대해 원인규명의 차원에서, 전통적인 원격탐사가 선형목적물을 감지하는 과정에서의 한계점을 지적하고

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비디오의 장점을 구체적으로 강조한다. 선형센서로서 많은 장점을 지니고 있는 비디오에 대한 과거의 연구가 어느 정도 현장의 수요에 부응하고 있는 지를 파악하기 위해 관련문헌에 대한 심도있는 조사가 수행되었다. 비디오가 선형센서로서 실무에서는 확실하게 자리잡고 이용되고 있지만, 비디오에 대한 학문적인 연구가 주로 area target위주로 수행되었음을 발견할 수 있었다. 연구동향에 대한 이와 같은 조사결과는 향후 비디오센서에 대한 연구방향을 정립하는 데 있어 중요한 시사점을 제공한다. 특별히 본 논문은 비디오센서의 장단점을 확실히 규명하고 미래의 연구방향에 있어 비디오 선형모니터링이라는 새로운 개념을 제시하였다는 데 그 가치를 지닌다고 하겠다. 궁극적으로 본 논문에서 제안이 비디오 선형모니터링의 가능성에 대해 새로운 전기를 마련할 수 있을 것으로 기대된다.

1. Introduction

Over the last 20 years, the majority of remote sensing research has been used to support global, national, or large area applications(Um, 1992) As a consequence, those charged with more corridor specific characteristics have benefited far less from the fruits of that research. The types of facilities which fit these criteria include cross-country pipelines, electric transmission lines and overhead cables, but also include railways, roads, highways, rivers, and coastlines. It is certain that more linear development will be continued in many places in the near future and it is also apparent from recent global trends that concern for environmental impacts of such linear development may be of world-wide importance (Um and Wright, 1996; Um and Wright, 1998).

There is, therefore, an imperative need to identify an appropriate remote sensor for environmental monitoring along the strip target. Detailed trade-off studies among typical airborne sensors are conducted to identify an optimal remote sensor which can supply the information needed in the most cost-effective manner. Such a comparative study for sensor characteristics highlights the inherent advantages of video in imaging a corridor target. Next, the result of extensive literature searches on video sensor is presented to demonstrate how much scientific gaps exist between the research scientists and the reality of the commercial user market in terms of optimal use of video sensor. This was in an effort to explore the future research direction in relation to the uniqueness of the video as a corridor sensor.

2. Limitations of traditional remote sensing techniques in a linear application

The characteristics of the ground target are considerably different from the conventional target on which traditional remote sensing has focused. It is necessary to acquire the remotely sensed image from an extremely low altitude, with a narrow angle of view along a long corridor. It will generally be necessary to acquire imagery with a ground field-of-view (swath width) of less than 100m for several hundreds of kilometres. To identify an optimal sensor for this target, four typical airborne sensors have been compared in consideration of the imaging requirement, based on target characteristics (as presented in Table 1). Satellite remote sensing is ruled out since the ground resolution is too coarse for the task being considered in the corridor target.

The most critical requirement for any remote sensing system is cost-effectiveness. The cost of inventory mapping with aerial photography

Table 1. Comparison of sensor characteristics

	The Daedalus 1268 ATM[1]	Airborne Imaging spectrometer (CASI)[1]	Photography[2]	Video[2]
Cost	Hardware purchase cost:£1M	hardware purchase cost: £ 0.25M	hardware purchase cost:35mm camera:(£300-400) 70mm camera (£1,000-3,000)	hardware purchase cost:S-VHS video camera(£1,500), £10 for three hours tape
Field of view[3]	73-90°	42° across track (90° is available)	24-130°	5-44°
Operational diagonal ground swath achievable[4]	443m-600m	230m-600m	127.5m-1286m	26m-242m
Number of bands	11 (71 available)	spatial mode:18 spectral mode:288	3	3 or 4
Wavelength(μm)	0.42-13 (visible, near, shortwave, thermal infrared)	0.4--0.915 (visible, near-infrared) 10-12bit	0.4--0.8 (visible near-infrared):wideband with spectral overlap	0.4-10 (visible near-infrared, mid-infrared, thermal)
Radiometric quantisation	16bit	No	usually 8bit[5]	usually 8bit[5]
Real-time imaging	No	No	No	Yes
Dynamic stereo coverage	No	No	No	Yes
User friendliness	No	No	Yes	Yes
Sensor	array of silicon detectors	CCD (Charge Coupled Device)	film	CCD
Image motion tolerability	No	Yes	No	Yes
Low-light tolerance	No	Yes	No	Yes

1. For the line scanner and imaging spectrometer, ATM and CASI have been used as examples, which the Natural Environment Research Council in UK presently use to provide airborne remotely sensed data for research by environmental scientists (Wilson, 1995).
2. The purchase cost of photographic camera and video camera were estimated based on current price of professional grade camera (e.g. S-VHS: Super-Video Home System).
3. A field of view was estimated by assuming 10mm-100mm focal length for 36mm by 24mm film sensor and 6.4mm by 4.8mm video sensor. [**Formula 3** Field of view (θ) is given by tan $\theta/2$ = half diagonal length of sensor format/focal length]
4. A diagonal swath width was estimated by assuming 300m flying height from the above range of FOV (Field of View). [**Formula 4** Diagonal swath width = 2* flying height * tan $\theta/2$ (θ: Field of view)]
5. Video and photo have own grey levels in analogue imaging condition. In digital environment, it is all dependent on the digitizing device.

would be a good standard against which other sensors could be readily compared. To monitor the 400km length of the corridor with aerial photography(in the case of 36mm format) of 100m swath, the number of photographs required is estimated at 10,000 frames (as shown below[1)]). The

1) Estimation of number of photos required for 60% stereo overlap.
Formula 1 Estimation of along-track ground coverage = (along-track format size of small format

cost would be increased several times for multi-year monitoring. It is considered too expensive to monitor the long narrow corridor frequently by aerial photography. Due to such limitations, corridor monitoring using aerial photography has not achieved operational status, although a few previous attempts have been reported (Hoover, 1974; Aird, 1980; Ellis and Long, 1984; Jadkowski et al., 1994).

The scanner and imaging spectrometer will be more costly and complex (complicated equipment and time-consuming analysis procedure) than photography. White (1997) states that the approximate cost for a new ATM (Airborne Thematic Mapper) is 1M, and for the CASI (the Compact Airborne Spectrographic Imager) £0.25M. For maintenance, roughly 10% of initial system purchase cost per annum is required. The hardware cost of the ATM is 666 times that of the S-VHS video camera (if it is assumed as £1,500). The initial purchase cost of ATM and CASI are too prohibitively expensive and further maintenance cost is also quite costly because, unlike video and small format photography, there is no large market for the ATM and CASI sensors. In the context of optimizing cost-effectiveness for this type of application, it is clear that video and small-format photography have decided advantages. [For this type of project these would not be purchased. The daily or weekly hire cost is more realistic.]

Another important element is the required optimal swath width. Field of View (FOV) differences provided by various remote sensing sensors will find application at different scales. The view-angle of the imaging device must be carefully considered first when trying to obtain remotely sensed data of a long, narrow target. Wide-angle imagery, such as line scanner and photography, generally covers a larger area of land surface than a smaller format system operated at the same altitude and with the same focal length lens as shown in Figure 1. For example, as presented in Table 1, under the same flight specifications (300m flying height, 10mm-100mm focal length range), a diagonal swath width (127.5m-1286m) of 35mm photography is much wider than that of video (26m-242m). Any single-scene image collected via such systems covers a wide area of surrounding features in addition to the strip. Such an image will, therefore, include a considerable redundancy of information which is not needed for corridor monitoring. Such wide-area coverage also disturbs the information content of the image by increasing spectral variance, through displaying unnecessary thematic ground classes. This can complicate analysis when doing digital image processing at a later stage(Um and Wright, 1999a).

In many instances, the two digital sensors and aerial photography are neither technically nor economically feasible for corridor monitoring and cannot provide the needed information in a cost-effective manner. Optimal sensor selection suggests the use of lower-cost systems to realize fully the potential of airborne remotely sensed data in a cost-effective application in corridor monitoring.

3. The value of video as a corridor sensor

The cheapest data among presently available

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photographic camera:36mm)* flying height (300m)/focal length (106mm) = 100 m

Formula 2 Net gain = along-track ground coverage (100 m)*4/10 (standard forward overlap 60%) = 40 m

The number of photographs required for stereo-cover = 400km/40m = 10,000 exposures remote sensors are generated from video, with a large amount of frames within a second (operational rate of 25 frames/s in the European PAL television system and 30 frames/s in the American NTSC system), and it is ideally suited to continuous data acquisition along the long/narrow corridors. Airborne video remote sensing, with a narrow angular view, can be applied in a fairly cost-effective manner to linear feature monitoring (requiring a narrow swath) by imaging the necessary ground target efficiently. For this particular application, the limitation of narrow view becomes a positive advantage and makes video particularly cost-effective(Um, 1997).

To achieve a narrow ground swath it is necessary to fly at very low altitude with longer focal length. This specification requires the use of very fast shutter speeds, such as 1/2000s, to avoid image motion. The CCD (Charge Coupled Device) sensor with greater light sensitivity than standard film, allows the use of faster exposure times than are typically used with photography, and low-altitude imaging with a narrow swath can be conducted without noticeable image motion effects during sensor exposure (King, 1995). For example, with the popular video CCD size of 6.4mm by 4.8mm, it is possible to cover a 40m swath from 600m (2000feet) flying height at 97.5 mm focal length setting, without any difficulties in terms of image motion and flight regulation. As a result, the use of airborne video data would fill an existing gap with its ability to gather image information of a land surface area quickly and under conditions of weather and time that would render aerial photography inadvisable. This is a very important attribute of video for low-level application.

The most frequently quoted shortcoming of existing video systems is the relatively coarse spatial resolution (as shown in Table 2). The resolution in video systems is commonly measured as horizontal and vertical resolution. The horizontal resolution means the number of black and white vertical lines which can be detected at the centre of the video picture while vertical resolution is examined by checking how many black and white bars can be distinguished vertically through the middle of the picture. However, the performance of a video system can also be evaluated according to the line-pairs per mm convention of photographic systems, via an empirical resolving power test such as the Kell conversion factor [Formula 5 one optical line pair $=2\sqrt{2}$ TV lines (Jensen, 1986)]. According to an empirical experiment by King (1995), the S-VHS video recorders have an image resolution

Table 2. Maximum approximate spatial resolution for video, low-cost digital camera, and 35mm film imaging in the horizontal and vertical image directions (H, V, respectively) in line pairs per milimetre (lp/mm). (After King, 1995)

	Data acquisition format	H resolution	V resolutio
Video Video	720*480 photo-sites, 6.4mm by 4.8mm sensors, super VHS recording	25	20
	720*480 photo-sites, 6.4mm by 4.8mm sensors, digitized directly	40	30
Digital camera	1280*1024 photo-sites, 9mm by 7mm	55	55
Digital camera	1280*1024 photo-sites, 21mm by 16.8mm	24	24
35 mm film standard	36mm*24mm	80	80

equivalent to 25 line-pairs/mm across the format fields in comparison to the potentially more than 80 line-pairs/mm resolution of 35-mm (small-format) film (Table 2).

Such absolute values could be quite misleading if they are used as the practical capability of the sensor for imaging real ground targets. Consequently, an operational ground resolved distance is probably a more useful representation of ground resolution. The ground resolved distance can be quite simply improved by reducing ground coverage (by using longer focal length) or by a lower level flight. In video, improving the ground resolved distance is more simple than with other airborne sensors, by using the narrow angle-of-view and by using the fast strobe shutter to avoid image motion. In fact, to ensure adequate ground coverage for around 20m corridor, the sensors with wide-angle FOV would require quite heavy optics in terms of focal length and exposure time and a much lower altitude flight specifications than in the case of video.

In reality, typical photography, with poorer low-light sensitivity, could hardly accommodate the low-light condition implied by using a longer focal length and fast shutter speed to avoid image motion. The reduced ground coverage would also increase the data acquisition cost proportionately for photography. Operational corridor inventories requiring hundreds or thousands of large-scale images would be much more expensive if using typical non-video airborne sensors. It is not feasible for other airborne sensors to be used practically for this type of application in terms of FOV, cost, and light sensitivity. Although film photography has better spatial resolution in terms of absolute value, it is unsuitable for this type of narrow target due to the inappropriateness of the imaging system in terms of wide angle-of-view, cost and low tolerance of image motion (Um and Wright, 1996).

Unlike with airborne scanners, imaging spectrometers or aerial photography, dynamic stereo coverage is achieved with airborne video in each single flight line, by recording a very large number of individual frames within a very short time interval. Video alone allows flexible post-flight selection of overlap percentage while others (e.g. photography) have a fixed overlap percentage at moment of exposure. Such dynamic stereo coverage makes video the best means of recording a large number of ground features over a given time interval, which is a main requirement in the case of long corridor monitoring. The tape can be played back as often as required, stopped at a critical point, or slowed down to capture a corridor target too fast for the eye and brain.

Such dynamic stereo coverage allows approximately 99% overlap between sequential frames (Um and Wright, 1999b). Theoretically, there should be less geometric and radiometric difference among closely adjacent sequential frames since they have more similarity in imaging conditions. As a result, mosaicking of video frames with abundant overlap could be a significant advantage since it would show better geometric and radiometric fidelity than with the standard 60% overlap in photography. Dynamic stereo coverage (achieved by high frame rates in analogue or digital-recorded video) is currently not possible with any other remote sensing system, including digital camera systems. For the moment, in terms of cost, the analogue and digital video recording is the only available system offering the advantage of dynamic stereo. In particular, video systems are fairly easy to handle, comparatively inexpensive and the system satisfies most of the user requirements for corridor monitoring. The users do not need access to the sophisticated remote sensing skills needed to operate more complex imaging systems. In this regard, video is often referred to as DIY remote sensing or a modern do-it-yourself data acquisition tool (Tarussov et al., 1996; Thomas, 1997). Aerial video is a technology that fills a niche that conventional aerial photographs can not meet. Video remote sensing offers a number of unusual characteristics different from the traditional sensors which can be highly advantageous for imaging and monitoring of linear features.

4. Previous research for videography in linear target

The acknowledgment of videography as a growing element in remote sensing is evidenced by addition of the term videography (although the term was first used by Vlcek in 1983) to the title of the 1987 American Society for Photogrammetry and Remote Sensing (ASPRS) Eleventh Biennial Workshop on Color Aerial Photography in the Plant Sciences. In this regard, the literature search has concentrated on papers and theses recorded since 1987. As a result of an extensive literature search, it is estimated that between three and four hundred papers have been produced on theory, processing techniques and applications since 1987, and several Ph.D. degrees have been awarded for a video remote sensing topic (Anderson, 1986; King, 1988; Lee, 1990; Skelton, 1991; Wunneburge, 1992). Several Ph.D. candidates are also presently pursuing topics related to video remote sensing. However, in spite of such activity in the field, there is a limited amount of study focused on the linear target.

1) Linear application in area-based target

The major groups who have initially shown interest in video are from the disciplines of agriculture and forestry. Video researchers can be divided into several broad groups. As a major group in the early stage of video research, in North America, video was initially investigated particularly by the US Department of Agriculture Forest Service (USDA at WESLACO, Texas, 1983 - present) and by the Faculty of Forestry at the University of Toronto (1983-1988, mostly by D. King who is now at Carleton University, Ottawa). The other major groups (1990-) are at Utah State University (water resource), Indiana State University (agriculture) and Stennis Space Remote Sensing Centre (agriculture and forestry). There are some other video research groups in Europe and Australia. In Europe the technique has been also studied, notably with the emphasis on forestry, as area-based targets in Finland and the Netherlands (Braam, 1992; Braam, 1993; Barker et al., 1993; Verhoeven, 1993). Also, in Australia video was investigated as a sensor for studying area-based targets (rangeland and agriculture) (Benkelman and Behrendt, 1992; Pickup et al., 1996; Louis et al., 1996).

Logically, if video is best suited to a linear target, then it would not be well-adapted to an area-based target due to the narrow angle of view. Quite a lot of research (not for operational application) has been done to use video as a tool for area-targets. Everitt et al. (1996) have developed a three-camera colour video system by mounting one camera in a normal 90 degree angle and positioning the adjacent left and right cameras at 35 degree angles, respectively. Also, to overcome the narrow angle-of-view, video frames acquired from multiple flight passes had been stitched with sidelap and endlap (Wunneburger, 1992; Neale et al., 1994; Linden and Hoffer, 1996). The side overlap processing will usually be made with video frames acquired from multiple non-sequential flight passes. The matching frames will probably have totally different radiometric and geometric conditions. Video mosaicking will then show serious deterioration in image quality(Um and Wright, 1999b). Furthermore, a huge effort of human labour (i.e. time) is required for mosaicking as soon as large areas are involved. With in-flight navigation, it is extremely difficult to achieve side-overlap when the FOV is very narrow. In this regard, King (1995) states very few applications have actually mosaicked the hundreds of frames necessary for area-based mapping.

Although video has not yet been successfully used for real area-based mapping (i.e. full area survey), there are quite a lot of operational applications of video as a strip sensing tool for area-based targets. Much agriculture and forestry work requires sampling of large areas. Therefore, operational applications of video have already been done as a basis for sampling forestry and agriculture. There would be quite a lot of operational uses for this purpose which are not reported as academic papers. For this purpose, video will completely replace the traditional photography due to various inherent advantages of video (cost, real-time imaging and light sensitivity). Therefore, most reported operational applications related to area-targets (not research) would belong to such a transect based approach (Myrhe, 1996).

Another linear application of video is to verify interpretation of satellite or other small scale images. Eggen-McIntosh et al. (1994) state that video transects of the scene were flown at a nominal 1,000 meters above ground level (AGL), with an 8.5 millimeter focal length video camera lens, producing an image minimum of 2 percent sample of the forested land covered by the Landsat TM (Thematic Mapper) scene. A video cassette recorder and television were used for manual verification and correction of interpreted TM print overlays. The quality of the video imagery for sample areas was acceptable for verification of satellite image interpretation. Slaymaker et al. (1995) used GPS-reference airborne colour video to serve as site-specific referenced data for Landsat TM classification of deciduous forests in the northern United States. They acquired continuous imagery along 1500 km of north/south and east/west transects spaced 15km apart in both the spring and fall. Two cameras were used: one with a wide-angle lens providing a 500m swath and 1m ground pixel size; the other with a 12x zoom lens providing a 30m swath and 6cm ground pixel size. The video was used to verify and improve satellite image classification result.

Airborne videography provides a means of acquiring a relatively large percentage of sample transects in forestry and agriculture or field verification of satellite image interpretation without the delay or cost of film processing. The video data will be much less costly than aerial photography or field investigation and could replace other existing remote sensors for this purpose. However, such research output from area-based targets would not be extended to the corridor target.

The user requirement for a corridor target is quite different from the sampling approach for area-based targets as discussed in next section (4.2). Corridor monitoring requires complete mapping of a long strip which requires mosaicking and change-detection through image to image registration, for which video is intrinsically suited. The past linear application of video in area-targets has not effectively assisted in the utilization of video as a linear remote sensor. Corridor mapping can use the strongest advantages of video for a narrow, long, linear target(Um and Wright, 1999c).

2) Limited research focused on a linear target

A major source of literature on video remote sensing are the proceedings of the biennial ASPRS videography workshops (held since 1987) and the first video workshop proceedings, of 1988. Around ten papers about the linear target have been presented in the proceedings during the past 10 years, while 59 of a total 119 papers are area-based applications and research (the rest the papers belong to video theory and processing). Papers on linear research are found sparsely in other remote sensing journals and conference proceedings (Flach et al., 1989; Kuo and Birk, 1992; Maggio and Wunneburger, 1993; Kuo, 1994; Raper and McCarthy, 1994). Although the number of papers are recorded as 10 for the corridor target, many of them are reworking of the same research project, which it is difficult to regard as separate research output. If the papers are recorded as one group, then the number of papers for corridor studies are estimated at three or four.

As a result, relatively few studies in comparison to area-based target have been recorded concerned with a corridor target, and many of those deal with river and water quality monitoring. Fisher and Moline (1992) quantified the areal extent of the floating meadows in the Amazon River Floodplain using aerial videography. Michael and Fenton (1992) used airborne videography to quantify and monitor river habitats as they relate to endangered fish. Their investigation found that the quality and costs associated with video are acceptable for river habitat monitoring. Utah State University and associated research groups have extensive experience in river/riparian quantitative analysis (Snider et al., 1994; Anderson et al., 1994; Panja et al., 1994; Bartz et al., 1994). New Jersey Institute of Technology has been modelling water variability in estuarine and river environments (Bagheri and Stein, 1992; Bagheri and Stein, 1994). Bagheri and Stein (1994) reported that multispectral video imagery clearly demonstrated its capability to monitor water quality under the most adverse weather conditions. An airborne video system has been used for monitoring of river environments by Yoshikawa et al. (1996). They report that the system proved to be more effective than using aerial photographs when the target to be monitored is long, and where continuous recording of detailed information is necessary. Klemas et al. (1996) reported that a solid-state video camera would be useful for monitoring water colour in a coastal environment.

Much of the previous research did not initially intend to promote the advantages, for the potential user, of video for a linear target although they can serve as examples for corridor application of video. Most previous uses were also not aimed at optimizing the advantage of video for a corridor target, but to test the potential of video in a specific type of application. For example, many of the recent studies of a corridor target have been presented by the Utah State University and New Jersey Institute of Technology. Their main focus was to solve specific issues in a wider research project, such as river/riparian analysis or water quality monitoring. It was also not an intended aim of most of the previous linear applications to demonstrate the potential of video to meet the demand for a suitable remote sensing tool as the government regulation of corridor facilities increased. The technical feasibility of video for a corridor target has not previously been investigated in the detail of this project. The ideal target to demonstrate the strength of video in a corridor application would be where a single video flight pass could cover the target continuously without requiring sidelap mosaicking among adjacent frames. Many of the previous studies mentioned above could not strictly be classified as corridor-based research, since multiple flight passes and sidelap mosaicking in those projects have been done over river and coastal zones. It is not appropriate, therefore, for the results of these studies to be directly extended to other types of long narrow target(Um and Wright, 1999b).

5. Operational application and future research direction

In spite of the lack of research on corridor targets, in reality there are some companies which are flying video commercially over linear development sites or there are corridor facilities managers (such as pipeline, railway) using video images operationally for corridor target studies (State, 1993; Blazquez, 1994; Sky Vision International UK Ltd., 1995; Cooper et al., 1995). Nortech Surveys operate in Canada and South-East Asia (Wanless, 1991) and Sky Vision International operate in USA and UK. Due to such inherent advantages of video for a corridor target, there could be a considerable amount of commercial application of video which has not been reported in the academic literature. It is believed that operational users, on the commercial side, have committed themselves to actual utilisation of these systems on a regular and commercial basis with little regard to related research. This observation suggests that there is a considerable gap between research and operational use of video in corridor target/ applications.

However, previous commercial applications of video for corridor targets have been limited to situations where the needed information can be acquired by visual interpretation. For example, video have been used for pipeline route survey (Johnston et al., 1989; Sky Vision International UK Ltd., 1995). The location of different types of geological feature and ecologically sensitive areas could be easily identified by on-screen observation of the video image. Video could provide indicative information concerning workability for pipeline construction works. Video have also been used for encroachment detection of the pipeline and for imaging of transmission corridors (Flach et al., 1989; Campanella et al., 1995). Corbley (1994) describes some of the visualization advantages of video over photography in pipeline monitoring. For this type of application, the general value of the video is associated with location, qualitative assessment, and access evaluation of specific ground features.

Although in previous applications video has been used successfully by adopting a visual approach to analysis, there are many field problems which require digital analysis of the data. Many applications can also be improved by including a digital approach, in terms of information extraction. The advantages and disadvantages of visual and digital approaches have been well summarised by Chuvieco and Vega (1990). For example, on-screen visual interpretation presents several problems, of which the main one is a failure to take full advantage of digital image processing. A computer-based image can be enhanced to satisfy the particular needs of the interpreter. In this regard, visual interpretation conducted in a digital environment could benefit from image processing since the human eye is unable to discriminate all the grey levels recorded in the digital values.

The past research of video focused on area-targets (not operational application) has tended to result in an undervaluation of the usefulness of video in a digital environment. If the application is related to a linear target, then the digital interpretation of video is relatively simple, since the mosaicking process requires only endlap among sequential frames. However, it is rare to see a demonstration of the practicality of a quantitative approach for a corridor target. As a result, most previous applications for a corridor target have been carried out in a qualitative and not as a quantitative sense. The past approach for linear video remote sensing inevitably leads to a lack of efficiency in terms of optimal information extraction. Ultimately, the lack of research focused on a linear target has hampered the wide use of video on an operational basis beyond present prototype status(Um and Wright, 1999d).

The operational transfer of the research output relies heavily on the initial understanding or assumption of client need, the sensor and ground target. Such a focus on area-based targets created scientific research problems (such as sidelap mosaicking and radiometric smoothing during mosaicking), without necessarily solving the operational problems. Much of the earlier research was conducted to solve problems created by the use of initially inappropriate target, which client may not have much interest for the research output. Such practices have resulted in the expenditure of time, labour and money on solving problems which were largely irrelevant in an operational environment (and also, possibly, some unsolvable research problems).

To tackle such practices, there is a definite need for more client oriented research which develops a technique for the application of video remote sensing in a more practical way. The strength of videography for corridor application should be further tested to optimize the advantage of such systems. More rigorous experiment and assessment has to be made to achieve widespread adoption of videography as a rapid, low-cost strip mapping method. Such a commitment will radically change the confidence and operationality of the research output, since realistic assumption for research problems(e.g. mosaicking with endlap) affects virtually every aspect of the VSM. The results of the academic research can, therefore, be used more realistically by the end user in an operational sense.

6. Conclusions

This paper provided a critical summary to understand fully the video medium in order to make the best use of its advantages to the ground target. However, due to the relative newness of video remote sensing, there are many weaknesses perceived in previous video research. Video has been researched for the past ten years or so, with a focus on area-based targets (generally not for operational application). As a result, much of the research has been conducted more or less for pure scientific experiment itself and did not usually serve to assist operational application of video in terms of cost, equipment and practicality. The observation in this paper suggest special consideration in future research direction for the airborne video. It is strongly suggested that future researchers should give a particular attention on the strength of video as a corridor sensor to improve the confidence and operationality of research output.

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Please note that the following abbreviations have been used for commonly quoted publications.

ASPRS: American Society for Photogrammetry and Remote Sensing
ACSM: American Congress on Surveying and Mapping
EOM: Earth Observation Magazine
IJRS: International Journal of Remote Sensing
ISPRS: International Society for Photogrammetry and Remote Sensing
PERS: Photogrammetric Engineering and RemoteSensing
RSE: Remote Sensing of Environment
RT: Resource Technology

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