The interpretation of orbital imagery using the Interpretoskop of VEB Carl Zeiss JENA

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Introduction

The Interpretoskop of the JENA Works has been used successfully in the Department of Geography, University of Sheffield, for studying orbital imagery obtained from the ERTS and SKYLAB satellites. The instrument's versatility, in being able to handle both 70 mm and 23 cm film, in both paper print and transparency form has been most useful in mapping natural resources from space photographs. The large magnification ability of this instrument, together with its rotating optical axes enables detailed stereoscopic interpretation to be carried out.

This paper attempts to illustrate that stereo viewing of orbital images using the Interpretoscope holds many advantages for the interpretation and analysis of natural resources.

Erts and Skylab Geometry

Fig. 1 (p. 179) illustrates how stereoscopic coverage of a test area can be obtained (van Genderen, 1973). Not only is it possible to obtain stereo from side-overlap on successive orbits (e.g. N and N + 1), but it is also possible to obtain stereo coverage with the RBV camera of ERTS by exposing the test site area from a certain orbit with the nadir point north of the test site (frames N or N + 1) and to record the same area 18 days later with the nadir point south of the test site (frames N + 18 or N + 19).

The excellent stereoscopic vision obtainable both in low and high latitudes from the ERTS's RBV camera system which has been praised by many principal investigators [9, 10], is due to the fact that the stereo-effect depends on latitude. Near the tropics, where side-overlap is minimal (due to the orbital characteristics of the satellite), relief displacement is greatest in this narrow overlapping zone. By contrast, in northern temperate areas and at Polar latitudes, while the side-overlap is much greater (and therefore of special value to the binocular study of MSS images over most of northern Europe), the impression of stereo is markedly less due to the change in the base-height ratio.

Although the impression of relief is seldom great, the ability to view the images stereoscopically, or at least to obtain binocular fusion, greatly reduces the signal-to-noise ratio. This is so partly due to the fact that twice as many silver grains are used to form the composite image, and also to the benefits that result from "binocular reinforcement" which occurs when one assigns one good eye to the study of one image, and the other to the study of its stereo-mate.

The role of perspective is very important in human interpretation of ERTS and SKYLAB data, for while the RBV cameras of ERTS, and the S190 cameras on SKYLAB have a central perspective, the MSS images obtained from the 4 band ERTS scanner and 13 band SKYLAB scanner are formed by the line-scan technique and therefore have a perspective line. One of the problems encountered in this investigation into the potential benefits and limitation of stereo-study of orbital data, was that the RBV camera system of ERTS-1 became non-operational only a short while after the satellite had been put into orbit, so that RBV images exist of only very restricted parts of the world (mainly parts of north and south America). Thus images with a central projection, of the type air photo interpreters are most accustomed to, are practically non-existent. This raised the further problem of whether the line-scan images provided by the MSS scanners on ERTS and SKYLAB could also be viewed stereoscopically, and if so, could any parallax of the type provided by photographs with a central projection be observed. In this study it has been observed that while both end-overlap and side-overlap provide true stereo parallax using the camera systems, the multispectral scanners provide true stereo parallax only in the side-overlap area, so that the only apparent advantage in the MSS end-overlap area is from binocular reinforcement. However, stereo parallax does occur in the end-overlap area of MSS imagery if one uses temporal data. That is, using MSS images of an area taken at different times, in which case a parallax difference can be observed. Besides the advantages of viewing camera images stereoscopically, an important benefit obtained from studying two different MSS coverages of the same area is that each has its particular look-angle with respect to the sun's rays.

Spatial Studies

Of special value in this study on stereo characteristics has been the JENA-made Interpretoskop (Fig. 3, p. 180), with its ×15 zoom magnification and rotating optical axes for easy orientation of the images. The optical system of this instrument features high image quality and extremely good colour rendition. In the image plane, the field of view is, depending on magnification v, 200 mm/v. This means the field of view is 100 mm in diameter when the ×2 magnification is used, or a field of view of 13 mm diameter with ×15 magnification. When used with film transparencies which have a relative absence of "grain" in comparison to paper prints, the greater magnifications are able to be used. The resolving power in the image plane is 100 lines per mm at ×15 magnification. Thus using 9"×9" transparencies at a scale of 1:1,000,000, one can use the ×15 magnification to enlarge the image to 1:66,000, a useful scale for natural resource surveys. Using photographic means, image quality is inferior when the original images are enlarged to such a degree. The one drawback of this instrument's large magnification, however, is that it lacks a pantograph attachment, so that not only does the image enlarge ×15, but if one is attempting to draw in boundary lines, the drawing pen is also observed at ×15 magnification by the interpreter. The rotating optical axes of the instrument allow rapid fusion of the images to occur. This overcomes a problem encountered by Poulton [10] (page 160) who had to reposition the images while moving about the stereo model. The Interpretoskop is also one of the few stereoscopes which has a differential magnification ability, allowing images at slightly different scales to be fused without effort (see Fig. 2a and 2b, p. 180). In case of differences in scale between two photographs, magnification compensation of up to 1:3 can be achieved with the Interpretoskop by simply adjusting the pancratic systems. On additionally changing-over one objective lens, the compensation ratio can be increased up to 1:7.5. Whilst scale differences of such magnitude do not normally occur in two successive images of one orbital pass by a satellite, in the case of images of a stereo-model originating from different satellites (e.g. one ERTS image and one SKYLAB image), this possibility of compensating magnification differences of such magnitude proves extremely useful and almost impossible to obtain by most other types of stereoscopes. Also, in common with many other types of stereoscopes, it allows both paper prints and transparencies to be viewed. The use of the ERTS and SKYLAB data in transparency form rather than as paper prints is strongly recommended for visual interpretation. One of the main advantages of viewing stereo pairs in transparency form is that much of the detail to be interpreted is rendered in dark tones on a positive image. Thus the use of rear-lighted transparencies (i.e. using transmitted light) results in better image illumination than is obtainable using reflected (incident) light from paper prints. Differential illumination of each of the images can be controlled in such a way that the image brightness of the two images appears to be similar when the interpreter looks through the two eyepieces.

The construction of stereograms has been described by Bernstein [3], and the various uses which Avery [2] has listed for stereograms can be adapted for use with orbital stereograms. A further capability of the Interpretoskop is its ability to handle both 70 mm and 23×23 cm connected roll data. This is particularly useful for studies of very large areas, as the use of these connected roll transparencies avoids the sorting and filming problems inherent in handling separate paper prints. This is therefore applicable to the MSS line scan imagery from ERTS and SKYLAB, as such imagery is not logically divided into discrete frames.

When interpretations of orbital imagery are made by means of visual stereoscopic analysis, much emphasis is placed on tonal variations. However, several important points need careful attention, for tests have shown that not all tonal differences observed on orbital images are related to significant differences on the ground, and not all ground differences are reflected by different tones. Thus similar ground features may have different tones, and different ground features may have similar tones. This problem is, however, common to all aerial and space photographs, due to the calibration problem (e.g. film processing may result in tonal variations not related to actual ground conditions (Thompson [12] page 515)). Thus by using stereoscopic examination, ground locations in all but very flat relief are made far more rapidly than when the "apparent" relief suggested solely by tone patterns, is examined monocularly. Increased reliability and speed of interpretation of tonal variations have been observed when the images are viewed stereoscopically, using the Interpretoskop, as one does not only have improved image quality but one can also use the association of tonal variations with landforms. The relationships observed between landforms and tonal differences make interpretations of vegetation and geomorphology easier.

An additional advantage of viewing two ERTS or SKYLAB images stereoscopically is that by so doing, one enhances the image contrast. For, although the ground resolution of ERTS's MSS images is 75 – 80 m, many objects in the terrain smaller than this are often visible (e.g. roads, bridges, irrigation canals, etc.). because of the strong contrasts between such objects and their surroundings. Bridges are a typical example, as these show up prominantly on orbital imagery. This is so because the bridge gives a high reflection of radiation, and water a low reflection, so that the signal received by the scanner of an 80 m ground resolution patch is dominated by the stronger bridge signal. By fusing two images of the same scene, one increases or fortifies this effect of contrast, and therefore facilitates the mapping of such features.

The Interpretoskop is also extremely useful for scanning the orbital imagery, and for preparatory work on the images. The scanning operation can be used for purposes of evaluating ERTS and SKYLAB image quality, determining the amount of overlap of different images of the same ground scene, and to identify certain "ground truth" sites.

Spectral studies

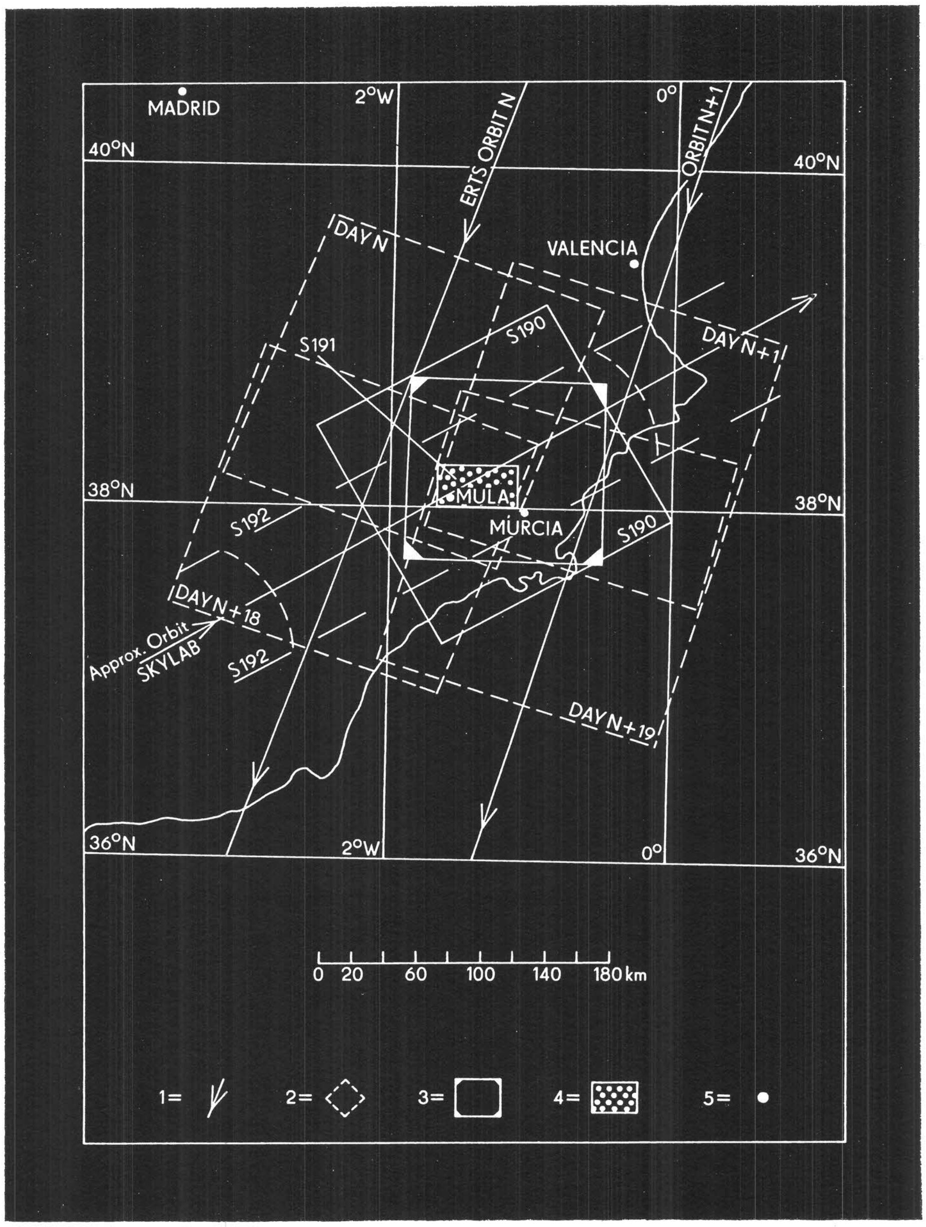
As well as standard stereoscopic image interpretation, the JENA-made Interpretoskop can also be used to fuse two of the ERTS and/or SKYLAB images which have been taken either from the same or different points of view, and which have different spectral, tonal or colour properties. It is possible to combine, for example, images of an area taken by band 4 and 5, 6 and 7, or a colour with a false colour photograph, or an RBV black and white with an S190 black and white. Many other combinations are posible. Bearing in mind some of the limiting factors mentioned earlier such as perspective and scale differences, such relatively simple techniques of image mixing – although they are sometimes considered rather unconventional – can form a useful experiment.

One of the problems facing a user of ERTS and SKYLAB imagery is that of the volume of data that these satellites generate. How, for example, does one interpret by visual means the 21 different images of the same as provided by the S192 13 band multispectral scanner, the S190 multispectral photographic facility, the S191 infrared spectrometer, etc.? With ERTS, having only a 4 band scanner, the problem is not as acute, as here one can use the colour composite images and view these stereoscopically. By using these colour composites, formed by combining the spectral information of three or four of the spectral bands onto one image, one has a product which is rather similar to a colour infrared photograph. In this way, one has not lost much of the information obtained in the original images, as well as having a product with which most

Fig. 1: Stereoscopic overlap areas in ERTS and SKYLAB photographs. 1 = orbit on two successive days in a period of 18 days; 2 = RBV scanning field of 185 km²; 3 = Murcia Province test site; 4 = Mula test site; 5 = important towns.

photo interpreters are familiar [1, 8] and which is ideal for use with the Interpretoskop. With SKYLAB, methods have now been developed to reduce the 13 images provided by the S192 scanner to two or three "new" images, with no significant loss of information. These techniques of data compression, often using principal components analysis [11], therefore allow one to study the two resulting images under a stereoscope, using visual means of interpretation. As well as these methods of data compression, which, it is to be hoped will soon form part of standard data preprocessing procedures, the ability of the Interpretoskop to fuse two different spectral images as mentioned earlier, is ideal for image mixing, and is a cheap, fast and effective method of image enhancement analysis.

1



Temporal Studies

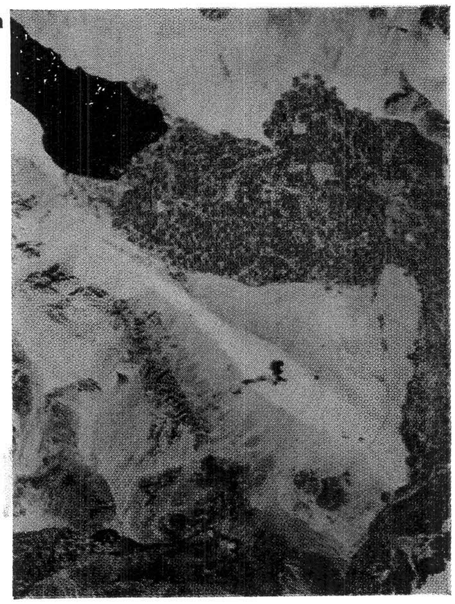
One of the main advantages offered by sensors operating at orbital altitudes such as ERTS and SKYLAB, is the repetitive coverage that they provide. ERTS covers the same area every 18 days, while SKYLAB covered the same ground area every 5 days. This ability to provide continuous sequential imagery is an aspect of earth resource investigation that is being investigated by many workers, in order to monitor changes in seasonal run off, agricultural cycles, etc. In order to carry out such temporal studies, one must be able to superimpose the images perfectly. To achieve this goal, many principal investigators have in fact developed complex systems of image registration. Once again, however, temporal studies can also be carried out by using simple stereoscopic (or binocular) examination techniques. The Interpretoskop is extremely suitable for this type of analysis, as with its differential magnification and rotating optical axes, it is possible to obtain a very good fit or superimposition, and with the two images fused under the stereoscope, one can proceed to examine the temporal changes that have occurred.

Another important aspect of the temporal data provided by ERTS and SKYLAB is that it aids in an appreciation of relief. By studying under the Interpretoskop the parallax exhibited by a shadow on repetitive images of the test site taken during different seasons of the year, one can obtain a useful indication

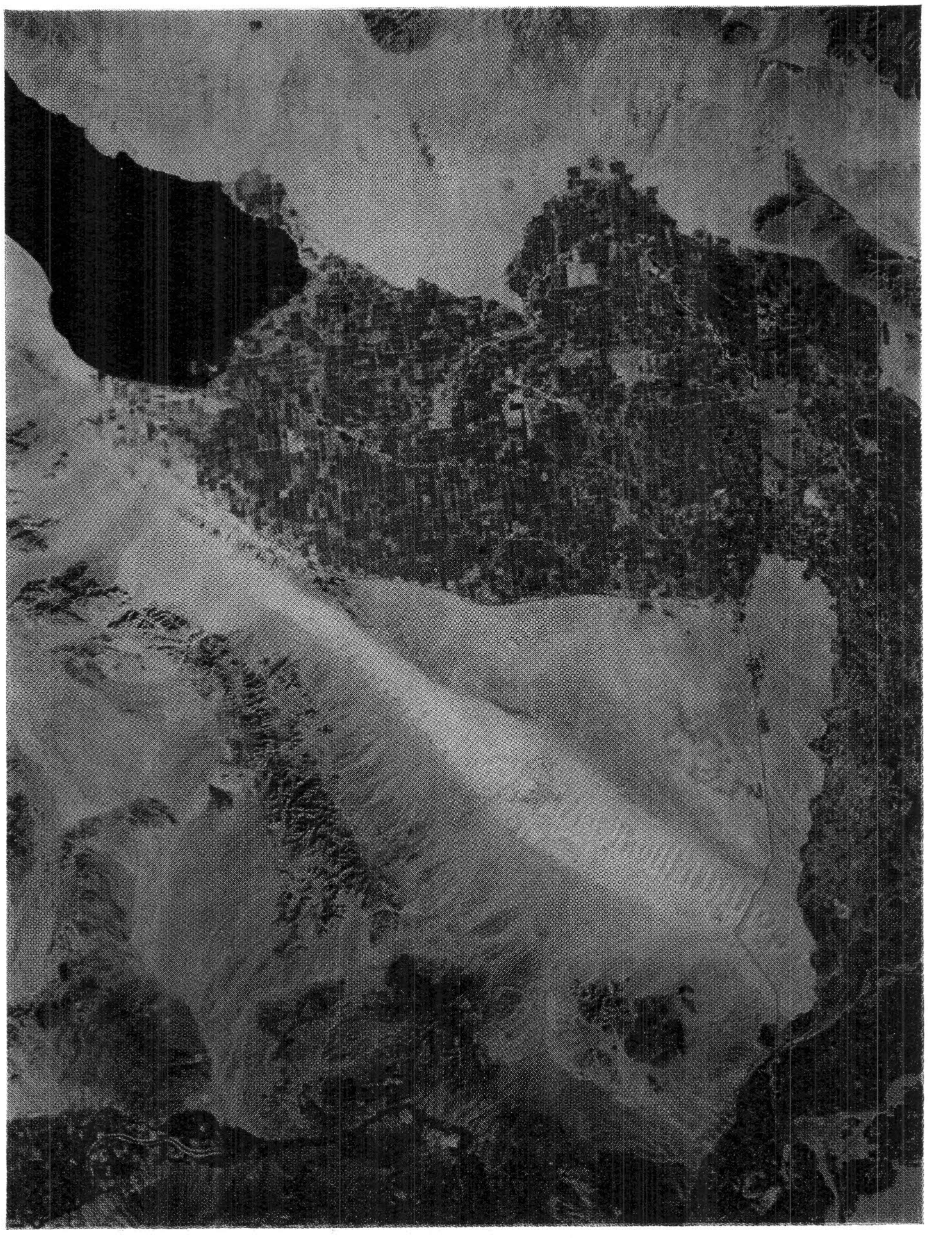
Figs. 2a and 2b: Stereopair of orbital images having different picture scales.

Fig. 3: The INTERPRETOSKOP interpretation equipment.

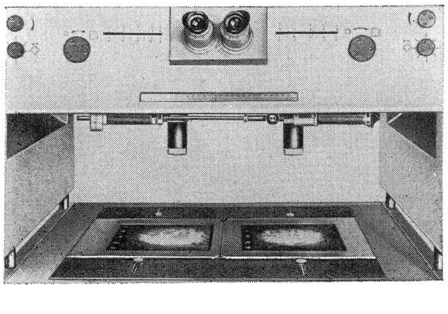
2a



2b



3



of relief. This effect, which has been described by Colwell [4] for aerial platforms, is particularly applicable to orbital imagery, where other methods of obtaining relief information are rather restricted. Thus on stereopairs of ERTS or SKYLAB imagery made by fusing overlapping images of an area taken at different times of the year in order to obtain shadow parallax, there is a marked increase in the ease of interpretation of terrain features, even though often very little parallax is discernible in the features themselves. The combination of true stereo parallax, plus shadow parallax therefore offers many possibilities to human interpreters for making meaningful analyses of orbital imagery.

Conclusions

1. The approach to visual image interpretation of both ERTS and SKYLAB data, with emphasis on both stereoscopic or binocular methods of analysis, and on multi-image handling of both spectral and temporal imagery is aided by using the versatility of the JENA-made Interpretoskop.

2. Of the three main characteristics of orbital data (spatial, spectral and temporal), the methodology of stereoscopic photo interpretation described can provide significant contributions to the study of the spatial and temporal characteristics of the images, by using the image characteristics of tone, texture, structure, pattern, size, shape, shadow, associated features, etc., as well as the relief effect obtained by both the true stereo parallax and the shadow parallax effects outlined in this paper.

3. The study of spectral characteristics has only been carried out at a very elementary level by the procedure of image mixing described in the preceding sections. However, new developments in methods of data compression may allow more detailed spectral studies to be made using the Interpretoskop.

4. The 23×23 cm and 70×70 mm format obtainable in both print and transparency form, is extremely suited to visual interpretation methods when using stereoscopic examination by means of the Interpretoskop.

5. Using the procedure of human image interpretation applied to orbital imagery, many earth scientists, who have neglected the important information source of ERTS and SKYLAB data because of their lack of sophisticated data analysis equipment, should be encouraged to use their experience in aerial photographic interpretation, and adapt this to the rewarding study of orbital imagery using the Interpretoskop of VEB Carl Zeiss JENA and the analysis techniques defined in this paper.

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