Appendix B
PHOTOINTERPRETATION AND IMAGE PROCESSING

Summary

Collection of images is only the beginning of aerial surveillance. They must be processed and interpreted to make the information they contain available as a basis for action or decision. Camouflage, concealment, and deception methods can be effective, but do not always defeat the photointerpretation and image processing steps. Image processing, the enhancement of pictures through filtering, pattern recognition, and contrast enhancement, seems amenable to various forms of automation. Automation can also assist in photointerpretation, but true automation of photointerpretation may lie far in the future.

Introduction

Interpretation of aerial photography requires that skilled analysts devote considerable time to each picture, using optical equipment of various kinds and a comprehensive knowledge of sought-for targets and their tell-tale traces, or "signatures." Photointerpretation is the art of eliciting information from photographs. Image processing, now largely done by computers, is the refinement of pictures so as to make them more amenable to photointerpretation. Photointerpretation and image processing each benefit from the repeated collection of imagery overtime.

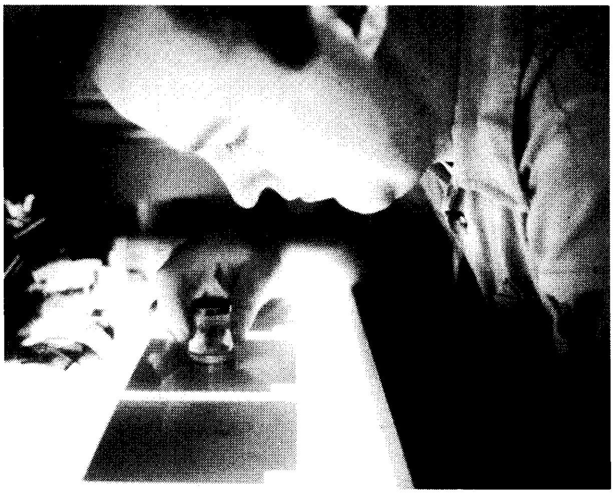


Photo credit: Department of Defense

Despite some degree of automation, the photointerpreter's task remains largely one of skill, patience, and memory.

Detailed analysis and reporting might well consume a person-hour per picture, or roughly a person-week of work to exploit fully the data taken in a single aerial monitoring sortie. Estimation of the time needed to process aerial photography is in some sense impossible because a photointerpreter's work is never done.[1] There is always some chance that extra time spent can result in extra information gleaned, perhaps crucial information not discerned initially: some photographs will have been set aside as unpromising, and even promising ones may not receive full exploitation. For example, British photography of the German missile test facility at Blizna (Poland) captured a V-2 intermediate-range ballistic missile; but the missile's image passed unnoticed through the entire image interpretation process, only to be discovered months later by a government scientist untrained in image interpretation but willing to go over the photographs "millimeter by millimeter for many minutes.

Examples of Photointerpretation

During **the Second World War, British photointerpreters examined imagery of the German test site at Peenemunde for signs of new rocket and jet weapons under development there. Constance Babington-Smith's account of how she found the V-1 ground-launched cruise missile merits quotation at length not only for the insights it gives into the photointerpreter's use of all the information at her disposal, but for the attitude with which she approached her task.**

> **I decided to follow the dead-straight road which led northward along the eastern boundary of the airfield toward the Baltic shore. I passed the limits of the airfield and went on toward the extreme edge of the island. To the right lay an untouched stretch of marshy foreland, but on the left there was a great deal going on-the long-term project of land reclamation for extending the airfield . . . . Right at the edge of the road there was something I did not understand--unlike anything I had seen before . . . . Rumors of "launching rails" for secret weapons had reached me earlier; and ever since I had been briefed about pilotless aircraft I had been on the lookout for a catapult of**

[1] Theoretical reasons, as well as experimental results, suggest that the cumulative probability of finding a target in a visual search, e.g of a photograph, depends upon the time devoted according to the function

$$p = 1 - e^{-kt},$$

where the constant k embodies the difficulty posed by the search because of the size of the target, the size of the search area, the contrast between the target and the background, and soon. The asymptotic approach of p to unity suggests that the interpreter's work is never done. See also Koopman, *Search and Screening* (Pergamon, *1980) especially* app. E.

[2] R.V. Jones, *Most Secret War* (London: Hamish Hamilton, 1978), p. 550. Jones had earlier been the first to find aV-2 image anywhere, in a picture of the test facility at Peenemünde (Germany) which had also undergone previous interpretation to no avail. (Jones, pp. 433-434.)

Photo credit: National Air and Space Museum, Smithsonian Institution

British reconnaissance photo of Peenemunde, site of German World War II rocketry research. The arrow indicates a V-2 missile lying on its side. Professor R.V. Jones discovered the V-2 missile in a photograph suoh as this.

some kind. I pondered over the photographs and reviewed what I had found. There were four of these strange structures. Three of them looked very much like the sort of crane that have a box for the operator and along movable arm. But the fourth seemed different, and it was the one that drew my attention most. It was evidently a sort of ramp banked up with earth-you could tell that from the shadow-supporting a rail that inclined upward towards the water's edge. "I'd better check with the Industry interpreters," was my first thought. "They probably know all about these things already. So I took the prints along to the Industry Section, and was told that these "things had been looked at long ago, and interpreted as something to do with the dredging equipment. Back at my desk, I gazed at the photographs again. . . . [On this basis, Flight Officer Babington-Smith asked to see a newer set of Peenemunde photographs.] Only the first print of the run showed it, so there was no stereo pair. The quality of the photographs was poor, but even with the naked eye I could see that on the ramp was something that had not been there before. A tiny cruciform shape, set exactly on the lower end of the inclined rails-a midget aircraft actually in position for launching.[3]

The following extract from R.V. Jones's *Most Secret War* recounts Dr. Jones's 1944 discovery of German V-2 intermediate-range ballistic missiles at a test facility in Poland. These missiles, not yet used in action, had previously been seen only at the Peenemunde test site in Germany. The account illustrates several features of aerial search for such weapons:

1. the importance of cuing by other intelligence sources, in this case signals intelligence;
2. the way infrastructure points to weapon presence;
3. the way preconceptions based on the way one's own side operates, or would operate, color one's interpretation of photographic evidence; and
4. the enhanced recognition ability conferred by previous sightings of the same target.

Jones wrote:

Something very odd had been taking place in Poland because Blizna[4] was from time to time dispatching what were called *Gerate* (apparatuses) back to Peenemunde. What could these be? I could understand things being sent from Peenemunde to Blizna for trial, but what would be worth sending back? I began to wonder whether these might be items such as rocket jets that had been tested, but there was no clue in the Ultra messages[5] regarding their nature. Certainly there were plenty of them, to judge by the numbers by which they were identified. The first number that I had was 17,053, about which I had learnt on 17 June, and by early July the highest number I had heard of was 17,667. How could I prove that these were rocket components? If only we had complete photographic cover of the Blizna area we could have found the launching site or the test rig, and perhaps found a rocket there; but even though I had requested further cover more than a month before, fresh photographs had not yet been obtained.

As I pondered, I tried to put myself in the position of the Germans working in unfriendly territory, and began to wonder whether--even with the rivalry between the German Army and the Luftwaffe-I would have used two sites, each of which would have to be defended, when there should be enough room at a single site to launch both flying bombs and rockets. I therefore took out again the 5th May photographs of the flying bomb compound, even though I knew these had been exhaustively searched at Medmenham. Going over them millimetre by millimetre for many minutes, I suddenly realized that a familiar outline had "clicked" into place with the memory of one that I had seen before---on the photograph of Peenemunde on which I had first found the rocket . . . .

But the account was not yet complete, because there was no sign of any launching apparatus. Our experts had assumed that the rocket would need to be fired from some sort of a gun at a speed of 100 metres per second to make it stable in its initial flight, and there was a large tower erection at Peenemunde which had been assumed to be for this purpose; but there was no such tower at Blizna. So on a subsequent evening I scanned the photographs again, looking for a concrete platform; ultimately in the center of the compound, and showing only faintly because that part

[3]Constance Babington-Smith. *Air* spy (New York, NY: Harper and Brothers, 1957), pp. 226-229.

[4]Known to Jones as a test site for the V-1.

[5]These were encrypted German radio signals intercepted by the British and decrypted. ''Ultra'' denoted the close hold the British kept on the results of this effort; "Enigma" was the name of the encryption machine used by the Germans.

> of the photograph was so light, was a square of about 35 feet wide. With this evidence and that from Molay,[6] could it be that the rocket needed no launching equipment more elaborate than a flat pad, and simply stood vertical, nose uppermost? If so this would explain the 40 foot "columns' we had sometimes seen standing at Peenemunde. The rocket would take off by itself, stabilized by gyroscopes and the deflectable 'jet rudders' we had found among the components mentioned in the Enigma messages.[7]

Babington-Smith, an expert, and Jones, by all accounts a most remarkable individual, make their work sound easy. In fact, considerable training is required. During the Cuban Missile Crisis, policymakers had found themselves relying on the testimony of experts despite having the photographic evidence directly at hand of Russian missiles being deployed in Cuba.

> Photographs were shown to us. Experts arrived with their charts and their pointers and told us that if we looked carefully, we could see there was a missile base being constructed in a field near San Cristobal, Cuba. I, for one, had to take their word for it. I examined the pictures carefully, and what I saw appeared to be no more than the clearing of a field for a fair or the basement of a house. I was relieved to hear later that this was the same reaction of virtually everyone at the meeting, including President Kennedy. Even a few days later, when more work had taken place on the site, he remarked that it looked like a football field.[8]

Change Analysis

Perhaps the most potent tool in the photointerpreter's hands is *change analysis*, the study of a target through interpretation of its evolving appearance. When she got the picture containing the V-1, Babington-Smith's attention was drawn to the new missile because of its appearance on a ramp that had been empty in the earlier picture. Babington-Smith later cited the German failure to "use comparative covers" (i.e., to perform change analysis), along with their lack of stereoscopic imagery, as the reasons that the German photointerpretation effort "never even got to first base" despite impressive basic optics.[9]

As will be discussed below, some mechanical aids are available to help the photointerpreter perform change analysis.

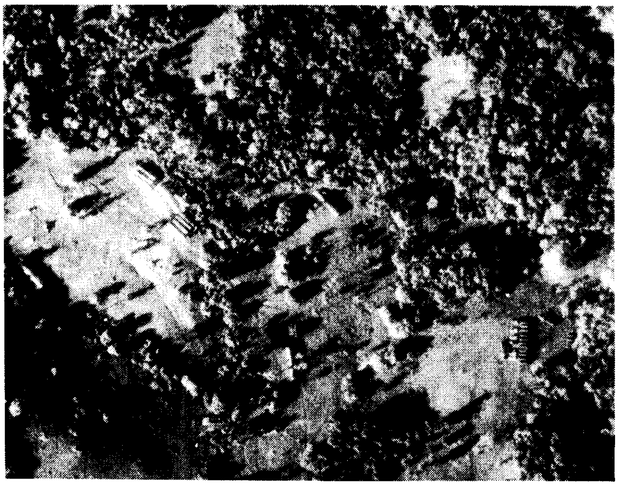


Photo credit: CIA and the National Air and Space Museum, Smithsonian Institution

This U-2 reconnaissance photo provides concrete evidence of missile assembly in Cuba. The infrastructure items shown here are missile transporters and missile ready-tents for fueling and maintenance.

A Test Case of Photointerpretation

The end of the Second World War provided American analysts the opportunity to measure the success of the photoreconnaissance effort to find antiaircraft guns and coastal artillery in the Japanese homeland.[10] This experience seems especially informative from the standpoint of a Conventional Armed Forces in Europe Treaty monitoring regime.

The study found that errors of interpretation (e.g., misclassification of an antiaircraft gun as a coastal artillery gun) occurred in 12 percent or fewer of the cases. Errors of omission occurred at an even lower rate, 5 to 10 percent, in areas where photographic coverage was complete, but went up greatly in areas not subject to exhaustive search. Coast defense guns, lacking the requirement to point upwards, were in some cases concealed to the point of invisibility to "any vertical and most oblique photography. ' In the case of antiaircraft guns, "strike photography, made while the guns were in use and camouflage removed, revealed the location of many guns which otherwise might not have been detected. " Also, "One case of complete concealment of a gun revetment by construction of a movable house built

[6] Such platforms had just been found near the Chateau du Molay by advancing Allied troops. Jones recognized the roads on the grounds of the chateau as having the same configuration as a previously unexplained set of roads on the foreshore of Peenemünde. These had been used, he deduced, to see whether the V-2's launching vehicle could maneuver in the chateau's driveway.

[7] Jones, op. cit., footnote 2, pp. 549-551.

[8] Robert F. Kennedy, *Thirteen Days* (New York NY: W.W. Norton& Co., 1971), pp. 1-2.

[9] Babington-Smith, op. cit. footnote 3, p. 259.

[10] This section is based on U.S. Strategic Bombing Survey (Pacific), Photographic Intelligence Section, *Evacuation of Photographic Intelligence in the Japanese Homeland, Part Nine: Coast and Anti-Aircraft Artillery* (Washington, DC: U.S. Government Printing Office, 1946).

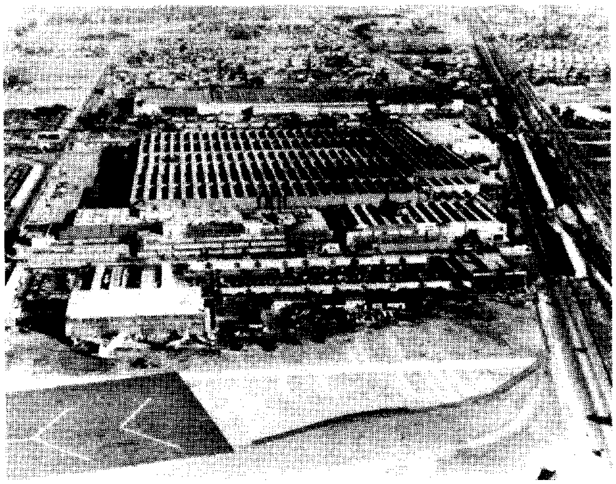


Photo credit: The Lockheed Corporation

Before concerns about Japanese attack led to concealment efforts, an aerial observer would have had little trouble finding and identifying this airplane factory.

Photo credit: The Lockhead Corporation

Painted buildings and sheets of painted fabric supported by telephone poles make the plant blend in with the surrounding suburbia. A careful photointerpreter might nevertheless see such telltale clues as the road to nowhere (arrow) and the airplane in somebody's yard (foreground).

on rails had not been detected by photographic interpreters." Dummy installations proved very difficult to discriminate from the real thing.

To interpret these results in terms of the lateral range curve paradigm of box 6-B, we ought to keep the 4-mile width and the steep shoulders, but lessen the height of the plateau in recognition of the fact that some targets within the picture will go unnoticed. It is difficult to estimate how far the plateau should be lowered: if we felt that targets in the picture (and thus in a region of complete coverage as cited in the preceding paragraph) have a 20-percent chance of being misclassified or of remaining undetected altogether during a normal amount of photointerpretation, we would lower the top of the curve to the 0.8 level, resulting in a sweep width of 3.2 miles.[11]

Camouflage, Concealment, and Deception

Attempts to frustrate aerial search are almost as old as aerial search itself-very old indeed if one counts ground animals' natural adaptations to avoid predatory birds. Targets can be ***camouflaged*** (made to appear part of the terrain), or *concealed* (merely hidden from view). Targets can also be left out in the open but made, through deception, to appear to be something that they are not.

The Second World War provides numerous instances of imaginative and effective uses of concealment and camouflage. The Lockheed Corporation, for example, provided elaborate camouflage for its Burbank plant, making the buildings appear to be rolling hills in suburbia. Technically, some element of deception was also used, in that artifacts such as houses and roads were included in the camouflage. (See photographs.) Note the use of rooftops painted on the runway and houses painted on the corners of the large hangar in the foreground. Close examination of the camouflaged plant shows certain flaws, such as a road leading to nowhere (arrow) and incongruous airplanes scattered in the left foreground of the picture. Though one need not be a highly trained analyst to identify the false buildings by their lack of shadows, the disguise might have been sufficient to confuse a bombardier.

Soviet military thinkers have placed great emphasis on the techniques of camouflage, concealment, and deception known collectively as *maskirovka* in Soviet military parlance.[12] The photo shows wartime efforts to disguise the Kremlin by painting rooftops on the telltale expanses of Red Square and the interior of the Kremlin. Again, the false buildings' lack of shadows gives them away in the picture (compare, for example, the Lenin Mausoleum—

[11] Because if we see 80 percent of the targets in a 4-mile-wide swath, we are *seeing* as many as we would see if we saw 100 percent of the targets in a *3.2*- mile-wide swath. The 20 percent figure agrees from the combination of the 12 percent misclassification and 5 to 10 percent omission rates cited in the previous paragraph but cannot be strictly derived from the Second World War experience; aerial search flights would hardly have the advantages cited for strike photography flights, but would be able to penetrate some kinds of camouflage with infrared photography.

[12] See *Camouflage: A Soviet View*, Soviet Military Thought, No. 22, translated and published under the auspices of the U.S. Air Force (Washington, DC: U.S. Government Printing Office, 1989). This is the U.S. Air Force translation of Victor Antonovich Matsrdenko's *Operativnaia maskirovka voisk* and *Maskirovka deistvii podrazdelenii sukhotputnykh voisk* by Anatolii Prokofevich Belokon and Sergei Grigorivich Chermashentsev.

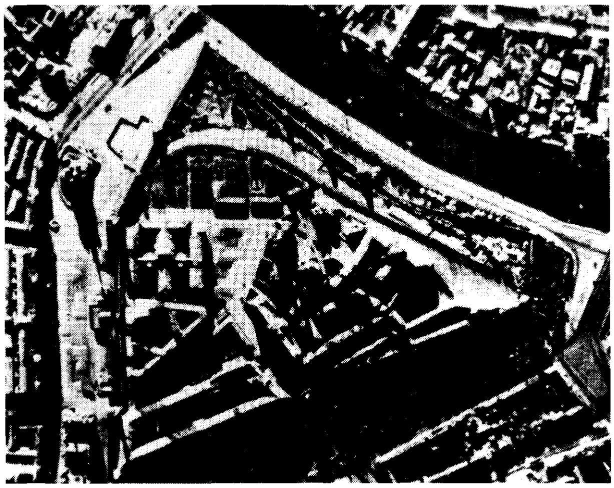


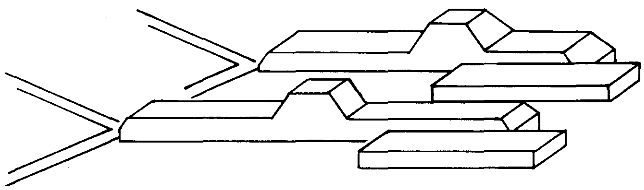
Photo credit: Photograph courtesy of the Department of Defense and the National Air and Space Museum, Smithsonian Institution

This photograph from World War II shows camouflage in the Moscow Kremlin and the adjacent Red Square. The Russians sought to break up the eye-catching open spaces by filling them with dummy buildings. To the trained eye, however, the dummy buildings are given away by their lack of shadows. Compare, for example, the Lenin Mausoleum (at the tip of the shadow cast by the spire of St. Basil's Cathedral) to the "buildings" nearby.

located at the tip of the shadow cast by St. Basil's--to the nearby sham buildings), but they might have helped confuse a bombardier looking for Moscow landmarks amid the havoc of a wartime bombing mission.

Limitations of Deliberate Concealment Measures— Many of the most memorable instances of military deception involve creation of the appearance of military hardware where none is present. Examples include dummy aircraft and tanks to fool image analysts and even false radio traffic to deceive electronic eavesdroppers.[13] Only in the most special of circumstances, however, would introduction of dummy TLIs make sense as a treaty-evasion ploy. One possibility would be the deliberate attempt to make the other side use up a quota of inspections wastefully. Such a ploy would run the risk of violating treaty language regarding interference with verification, or at the very least of showing "bad faith" in compliance matters. Another possibility would be to set up an apparent violation so as to be vindicated when, for example, the seeming SS-20 transporter-erector-launchers (TELs) turn out to be tank trucks; then, after a while, real SS-20 TELs could be deployed with confidence that

Figure B-l—Original Scene



Succeeding figures will show how this scene might appear at various stages of image processing. For clarity, these figures present the scene as if the sensor detected objects' heights, not their brightnesses.

SOURCE: Office of Technology Assessment, 1991.

no further violations would be charged.[14] Still other deception possibilities could be motivated by the desire to test the other side's monitoring capabilities.

The mere use of camouflage, much less the invocation of a threatening-sounding term such as *"maskirovka,"* does not guarantee success. During the Second World War, German shipyards used carefully manufactured pieces of camouflage to hide work on U-boats. British photointerpreters monitored the progress of the submarines' construction by careful observation of each new camouflage module as it was deployed.[15] Thus, detected camouflage efforts may be worse than useless, calling increased attention to suspect sites.

Image Processing

This section briefly illustrates a few methods of improving images, using cartoon-like images-not actual photographs—in which can be seen individual picture elements ("pixels": these are generated directly by electro-optical devices and could be created from photographic images) and the transformations they undergo. For clarity, these cartoons are made to look somewhat like possible aerial monitoring targets. Inmost actual pictures, the brightnesses of individual pixels do not correspond in such a simple way to the heights of the objects pictured.

We will examine three sample methods of image processing: contrast enhancement, filtering, and pattern recognition. The first two methods address the problem of retaining the target's image while rejecting unwanted impurities. The third assumes that a good image of the target lies somewhere in the picture but needs to be found.

The original scene is pictured in figure B-1: two submarines are pulling into dock. If digitized, the scene might look-very simplistically-as shown in figure B-2.

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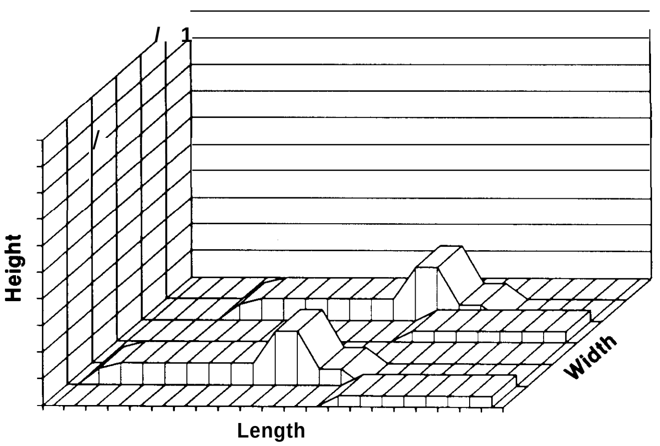
[13] Ibid., pp. 96-98.

[14] In the same vein, the British deployed masses of dummy artillery at El Alamein: the Germans, initially fooled, eventually caughton, whereupon the British replaced the dummies with the real thing. R.V. Jones, *Reflections on Intelligence* (London, England: WilliamHeinemann Ltd., 1989), p. 123.

[15] Babington-Smith, op. Cit., footnote 3, p. 113.

[16] This term, from electrical engineering, refers t. that which is received but not wanted, in contradistinction to "signal," that which is received and wanted.

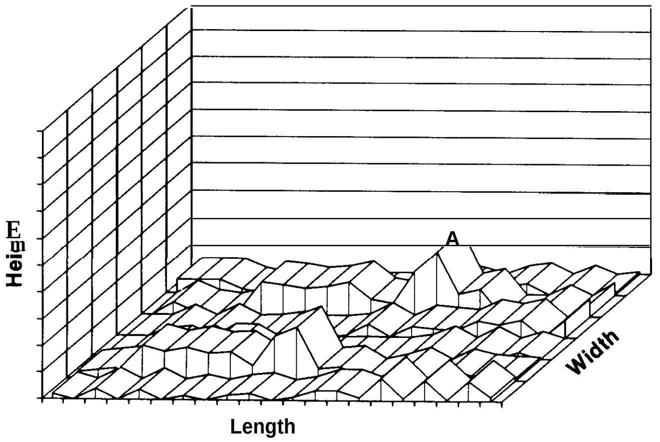
Figure B-2—Digitized Scene



After digitalization, the submarines' images have the boxy look associated with computer graphics.

SOURCE: Office of Technology Assessment, 1991.

Figure B-3-Digitized Image With "Noise"

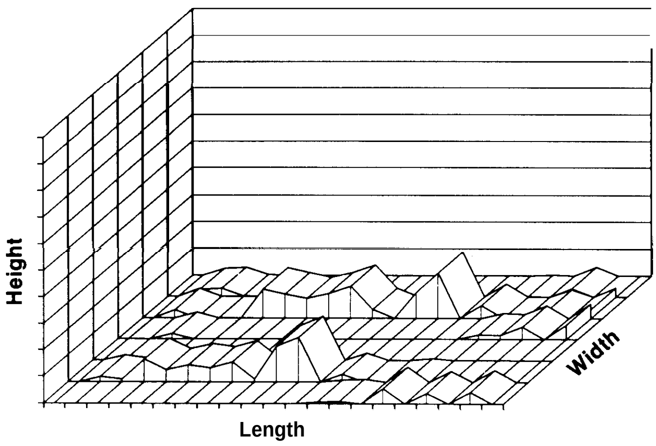


The received image will contain not only the digitized scene information, but also-inevitably-some electronic "noise" that distorts the image.

SOURCE: Office of Technology Assessment, 1991.

"Noise,"[16] however, inevitably intrudes and degrades the image: the degraded image is shown in figure B-3. Any image-processing method seeks to mitigate the effect of noise by making the target stand out more from the background. However, the method doesn't "know" for sure what is the target and what is the background. It must therefore proceed on the basis of some a priori assumptions about what traits will characterize the target and then

Figure B-4-Enhanced Contrast Image



One way to recover some of the clarity of the original scene is to enhance the contrast by showing only how much each cell stands out from its neighbors. The human eye uses a similar process to increase image clarity.

SOURCE: Office of Technology Assessment, 1991.

process the picture so as to increase the salience of those traits. If the traits have been well-chosen, increasing their salience will increase that of the target.

Contrast Enhancement-Contrast enhancement proceeds from the premise that the target's brightness is likely to differ from that of the background. On this basis, the contrast-differences in brightness between light and dark regions of the picture--is increased in the hope that the targets' outlines will become more apparent.

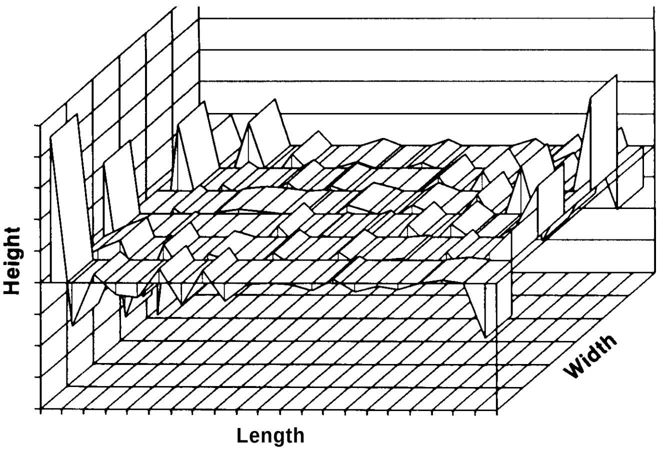
This method of image enhancement is performed naturally in the human retina, in which cells respond to light not only by emitting a neural output but by reducing that of their neighbors.[17] Such "lateral inhibition" results in an increased perception of contrast because the illuminated cells near a border between light and dark regions of the image receive no inhibition from their unilluminated neighbors on the other side of the border, while the cells in darkness near the border have their already-minimal output further reduced by their neighbors in the illuminated region.

Lateral inhibition can easily be implemented in software. Figure B-4 shows the image after contrast has been increased by dimming each cell in proportion to the brightness of its immediate neighbors and, to a lesser extent, the brightness of its neighbors two cells away. Notice how the images of the submarines and docks, though still "spikey," stand out more from the noise-induced clutter.

16This term, from electrical engineering, refers to that which is received but not wanted, in contradistinction to "signal," that which is received and wanted.

17R.L. Gregory, *Eye and Brain*, 2d cd., (New York, NY: World University Library (McGraw-Hill), 1973), p. 76.

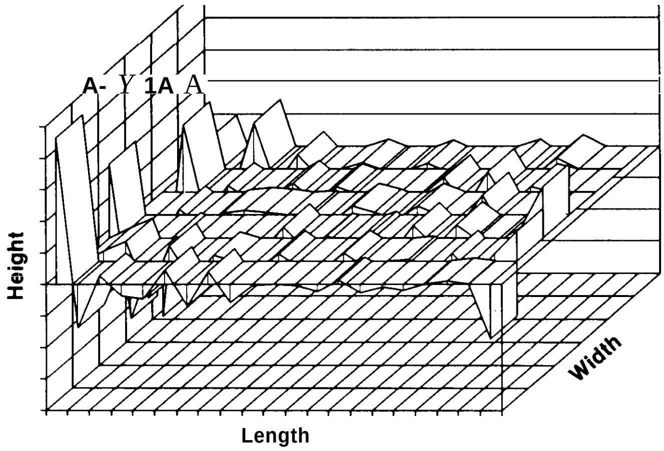
Figure B-5-Spatial Frequency Transform



A more ambitious route to image clarity starts by considering the image as a combination of waves (running lengthwise and widthwise in the picture) and plotting the amplitudes of these waves. The large spike in the left foreground, for example, is the "wave" with a frequency of zero in each direction-its amplitude is the average height of an object in the scene.

SOURCE: Office of Technology Assessment, 1991.

Figure B-6-Filtered Spatial Frequencies



Whereas the submarines and the docks have some regularity to them, the unwanted "noise" in the image varies irregularly from cell to cell. In spatial frequency terms, it therefore has high frequencies, lengthwise and widthwise. To eliminate it, the image processor zeroes out the high frequency cells in the upper right of the spatial frequency plot.

SOURCE: Office of Technology Assessment, 1991.

In a more realistic setting the targets would be more than one pixel wide, and would thus more closely correspond to the concept of contrast enhancement as "edge enhancement. "

Spatial Frequency Filtering—Another approach is to assume that the noise. is random and thus that the noise level in one pixel will bear no relationship to the noise level in other pixels. Targets, however, can be assumed to occupy more than one pixel, so that the presence of some part of the target in a pixel makes adjacent pixels likely to contain parts of the target as well. Furthermore, the target's brightness can be assumed to fluctuate less than does the noise level. In the received image, therefore (see figure B-3), the signal (the wanted part of what is received) varies less than does the noise (the unwanted part of what is received.)

Fourier transform methods and their close relatives[18] allow the decomposition of signals into their component frequencies.[19] Though most commonly used on signals that are functions of a one-dimensional variable such as time, these methods can be used on two-dimensional images, producing an image in the "transform domain. " Figure B-5 shows the Hartley transform of figure B-3 and, like the third picture, represents the received signal-plus-noise version of the scene showing the submarines pulling into dock. Because, as argued above, noise is uncorrelated from cell to cell in the original received image, the majority of the noise content is contained in the upper righthand corner of the picture, whose cells represent the amplitudes of rapidly fluctuating components. By artificially lowering these components' amplitudes to zero, we may hope to eliminate most of the noise. Inverse transformation of figure B-6-the same as figure B-5, but with the high-frequency cells zeroed out—shows (see figure B-7) the submarines and docks clearly, albeit with some distortion and residual noise.

Again, in a more realistic setting, the targets would be larger compared to the pixels than they are in our example. Therefore they would produce an even stronger low-frequency content in the image and the spatial frequency filtering approach would work even better than it does in our simple example. Larger images could contain non-target features, e.g., rolling hills, far larger than targets. Elimination of the images' low spatial frequency content would filter out these features.

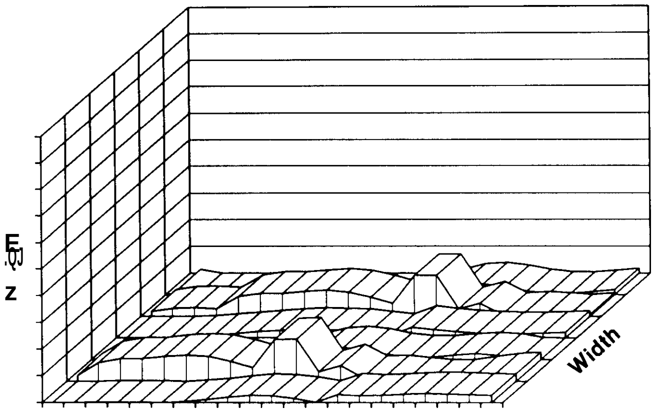
Pattern Recognition—A problem related to extracting a target's image from superimposed random "noise' is that of extracting a target's image from its surroundings. This problem arises when the imaged region is large compared to the target, leading to the need to search within the image.

The difficulty encountered when attempting to computerize pattern recognition is easy to understand when one reflects on the difficulty of instructing (without recourse

[18] Such as the Bracewell or "Hartley" transform used here. This transform has two advantages in the present application: exact reciprocity of the two domains and the exclusive use of real arithmetic.

[19] If one thinks of the original signal as viewed on an oscilloscope, the Fourier transform shows the same signal as viewed on a harmonic analyzer.

Figure B-7—Inverse Transform of Filtered Transform



With its noise-dominated high- frequency components eliminated, the transformed image is untransformed back from the frequency domain to the original domain. The contours of the submarines and docks are now much more clearly visible than in Figure B-3.

SOURCE: Office of Technology Assessment, 1991.

to pictorial representation) another person to recognize unfamiliar patterns even within a limited domain. Consider, for example, the task of teaching somebody, *through words alone,* to recognize and distinguish dogs of the more than 100 different breeds covered in atypical dog book. Automation of this process is notoriously hard; the general problem of pattern recognition has posed great difficulties over the years despite concerted efforts to solve it. Successes have come only when the problem was somehow restricted to a particular--often very small—domain.

One area of success in pattern recognition has been the guidance of cruise missiles. Terrain Contour Matching (TERCOM) and Digital Scene Matching Area Correlator (DSMAC) systems allow a missile to navigate by comparing passing scenery to stored images. These systems, however, deal with the recognition of whole scenes expected along the route or in the target region, not with the recognition of specified targets amid arbitrary surroundings.

Two-dimensional Fourier transform methods and their relatives can discern the presence of a target's image amid a clutter-filled scene by capitalizing on the fact that although the target could be located anywhere within the scene, its image in the transform domain will always appear in the same place. A simple check of that region of the transform domain will reveal whether or not the target was present in the original image. Further subdivision and retesting of the original image can help narrow down the location of the target, if it is found to be present at all.

The use of a lens to accomplish the Fourier transform simplifies the implementation of the above idea. The transformed scenes are captured on a transparent medium, as is the sample target image. One then shines light through the superimposed transforms of a scene and the sample target onto a screen; a bright blur will appear on the screen if the target appears in the scene.[20]

This method suffers from significant limitations, notably that the image must be known exactly and that although it can be detected regardless of its location within the original scene, it cannot be detected unless it is in the proper orientation. In practice, the latter restriction requires that one test the transform domain for images of the target in all orientations by rotating a test image 360 degrees. Even more problematical is that two images of the same object will differ in far more respects than orientation: scale, illumination, and configuration of movable parts, e.g., turrets and guns, will all vary nom image to image.

Change Analysis--The process of inspecting pairs of pictures to see what has changed can be automated if those features that remain unchanged from one picture to the other are-or can be brought to be--superimposed. Features that differ from one picture to the other can then be made to stand out by a viewing device that rapidly alternates from one picture to the other, causing discrepancies to flicker. In the case of halftone (black and white) pictures, copies can be made in complementary colors (e.g. one in green and white and the other in red and white) and the copies superimposed. Unchanged features will then appear in gray, while features that differ from one picture to the other will appear tinted, owing to incomplete color cancellation. In the case of color originals, a similar effect can be obtained by suppressing one of the three primary colors in one picture and another color in the other picture.[21]

Observations

The preceding discussion suggests that while automation can provide considerable assistance with *image processing* (by, as we have seen, increasing contrast or filtering out "noise" in the picture) it has yet to make a comparable contribution to *photointerpretation* as such: the principal contributions to interpretation are really just means of making interesting parts of the image (such as changes) stand out. True automation of interpretation, or even of search, lies in the future. One could say that photointerpretation remains an art, albeit one whose practitioners benefit from some advanced tools.

[20]See K. Iizuka, *Engineering Optics,* 2d ed. (Berlin, Germany: Springer-Verlag, 1983), pp. 288-290.

[21]Discussion and some good examples of this technique appear in Mien V. Banner, *Overhead Imaging for Verification and Peacekeeping* (Ottawa, Canada: Arms Control and Disarmament Division of External Affairs and International Trade Canada, 1991), pp. 15-19.