*Problem Analysis and the Role of Fundamental Image Extraction Techniques**

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ABSTRACT: *An operations analyst in the reconnaissance and information systems fields is called on to solve or to contribute to the solution of varied problems such as the development of extraction techniques for special subjects and/or sensing systems, evaluation of information outputs expected from image-type reconnaissance and information systems, model design, compilation of operational manuals, etc. Expeditious, reliable and skillful problem-analysis requires a systematic design which is based on fundamental concepts. It is considered that the fundamental image extraction techniques are (1) diagnostic element analysis, (2) layout or pattern analysis, (3) association analysis, (4) indicator analysis, (5) environmental analysis, and (6) integration analysis of the former five analysis techniques. The role of these fundamental techniques in problem analysis is discussed briefly.*

REFERENCE has already been made by former speakers at this ACSM-ASP meeting to information systems for various objectives. It can be recalled that all such systems required a transformation of information from an image form, such as on an aerial photograph, to coded form, in either digital or word form. This transformation or extraction is one of the operations that must be performed but it is one of important operations. This discussion is concerned with the extraction operation by which complexes and objects are identified.

All that we need to do is read accounts in the newspapers and magazines in order to gain a real appreciation of the improvements in current sensing-systems and new ideas with respect to new sensing-systems, such as photographic, television, line-scan, near-infrared, far-infrared, radar, etc. and with respect to new platforms, such as faster aircraft, guided missiles, and satellites.

An operations analyst who is concerned with the extraction of information from raw data and the analysis of this extracted information, and who is engaged in research and development studies of airborne data gathering systems, and of information systems, is called on to solve or contribute to the solution of varied problems. Some such problems might be

(1) development of extraction techniques to identify given subjects as presented by one or more image-type sensing-systems;
(2) development of extraction techniques to identify numerous subjects as presented by a specific sensing-system or a specific combination of sensing-systems;
(3) analysis of the evaluated information outputs to be expected from a specific sensing-system or specific sensing-systems;
(4) evaluation of an entire information system;
(5) design of a model for problem analysis;
(6) development of a simulation technique;
(7) compilation of operations and training manuals, etc.

Expeditious, skillful and reliable problem-analysis requires a systematic design or approach which is based on more fundamental concepts and less on empirical developments. The operations analyst must be able to contribute to a refined design of the over-all problem, and to design his own problem analysis so that it is compatible with the over-all operations analysis, and so that it will provide the most reliable

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contribution possible.

Extraction techniques which are based on specific and fundamental concepts are essential to maximize the contribution to problem analysis. The problem may be concerned with the probability of correct detection, recognition and/or identification of specific items or of specific complexes, such as are registered or presented on an aerial photograph taken under certain conditions.

It is considered that the fundamental extraction techniques are (*1*) *diagnostic element analysis*, (*2*) *layout analysis*, (*3*) *association analysis*, (*4*) *indicator analysis*, (*5*) *environmental analysis*, and (*6*) *integration analysis* which is a combination of any two or more of the previous five techniques. One or more of these techniques is applicable to each subject and to each sensing-system. Of course there are rather well defined reliabilities associated with each combination of subject sensing-system and extraction technique. Each extraction technique and the roles of the techniques in problem analysis will be discussed briefly.

Preliminary remarks are in order with reference to terminology which will be used in the discussion. The term "complex" is considered as consisting of two or more elements. The complex may be an installation of some type, such as an industrial installation or a military installation, or it may be a single object. The elements which make up the complex are considered as "components" of the complex, that is component objects of an installation or component features of a single object.

Diagnostic element analysis is a technique by which a complex is identified by determining the presence of each of an absolute minimum number of elements which individually, but usually in combination, is characteristically unique to the respective type of complex. Each type of complex is usually composed of several components which are essential to the functional performance of the complex. For example, in a coke plant we might say that the distinctive functional components are a stockpile of coal, possibly a coal treatment plant, conveyor, coaling tower, coke oven battery, and quenching tower. The diagnostic elements need not be the larger elements, linear elements, nor the more prominent elements.

It is believed that there is usually overinterpretation of aerial photographs for purposes of identifying complexes. More elements are identified than necessary in order to make a complex identification which is considered to be adequately reliable. In reality, the probability of a correct complex identification is not increased by an identification of any elements in addition to the diagnostic elements. Some of the additional elements may be characteristic but not uniquely exclusive in combination to the respective complex, and thus not diagnostic. Thus, for complex identification purposes, the person extracting the information from raw image data can restrict his attention to determining the presence of only these diagnostic elements.

In the precise sense a person might consider that the presence of all diagnostic elements must be determined by specific identification of each, independent of the identification of the other diagnostic elements. In reality the complex can be identified by determining the presence of some diagnostic elements by identification, and the presence of other diagnostic elements by recognition. This can be accomplished with no significant reduction in the probability of correct complex identification. This variant of the basic technique may be utilized to minimize to some degree the analysis necessary for a reliable identification of the complex. Only rarely could diagnostic element analysis be accomplished by determining the presence of elements by a combination of identification, recognition, and detection. Utilization of detection would usually necessitate the use of other basic but more subtle techniques, such as association analysis, layout analysis, environmental analysis, or indicator analysis.

Diagnostic element analysis places the greatest resolution requirements on the sensing-system and the reconnaissance-system. In general, the technique is the most reliable. A reconnaissance-system designed to diagnostic element analysis requirements would be more difficult to spoof with deceptive techniques. This is the technique which is most readily communicated in training since the technique is less abstract and less subtle than other techniques. Reference manuals can be compiled in a more simple manner and with less effort for utilization of this direct extraction technique. The technique places the least requirements on the skills of the extractor. When used by the less skilled extractor this technique provides higher probabilities of correct complex identification than would occur if these extractors used the more abstract techniques. However, the skilled extractor should be able to accomplish the identification of complexes by some of the more abstract techniques with probabilities as high as when he uses diagnostic element analysis.

This diagnostic element analysis technique would usually provide more precise information for problem analysis, such as with respect to (1) *reconnaissance system design and analysis* or (2) *information system design and analysis*. With this technique less analysis would be left to the judgment of the operations analyst. However, restriction of problem analysis to such an inflexible extraction technique would severely limit the information outputs that could be obtained from a reconnaissance system or an information system.

Layout analysis is an identification technique by which the complex is identified by determining the arrangement of selective elements which we may call layout or pattern elements. Some types of complexes have functional arrangements of component elements. The functional arrangement may be due to the sequence of processes which must be performed, such as in an industrial plant. In another case, the functional arrangement may be due to dispersal for protection, such as in the storage of explosives. The layout then consists of elements which in their aggregate arrangement give the respective complex a distinctive layout. This layout is then an indicator of the type of complex and of the types of elements present.

Layout analysis minimizes the emphasis on individual component element identification. The basic layout elements may be all of one type in some complexes, such as in an explosives storage area. In other complexes the distinctive layout elements may be several types, such as the runway, taxiway, hardstand, etc. of an airfield. It then becomes readily apparent that emphasis for determining the presence of component elements may be less on identification and more on recognition, and of great significance even on detection. Depending upon the respective case or complex, the probability of correction identification by layout analysis may not be increased by the recognition of some "detection elements" and by the identification of some "recognition elements."

Association analysis is a technique by which a complex is identified by determining the presence of an essentially specific and characteristic combination of component or association elements. From an association viewpoint a complex is composed of a group of objects, features or elements, which characteristically occur together, have specific relationship to each other and to their surroundings, and have a definite organization. The association consists of the essential functional components of the complex even though a few such functional elements may be common to several other complexes. Association analysis is especially applicable when diagnostic element analysis cannot be utilized. Association analysis may require determining the presence of a few more elements, but not exactly the same set of elements as diagnostic element analysis. The person extracting the information from the raw data restricts his attention to determining the presence of association elements.

The presence of association elements is determined by a *combination of identification, recognition and detection*. It is important to note that for each respective association there are "identification elements," "recognition elements," and "detection elements." No significant increase of probability of correct complex identification is obtained by over-identification of the association elements.

Indicator analysis is a technique by which the presence of complex elements is determined by ascertaining the presence of some other associated element, feature or object. It is specified that the complex element of interest is not registered on the sensing-system presentation in an identifiable, recognizable, or detectable form. The complex element of interest may be too small to be registered or it may be concealed or obscured, either intentionally or unintentionally.

Indicator analysis may be applicable on the one hand to complex identification exclusively and on the other hand to an integrated analysis technique, in combination with diagnostic element analysis or any one of the more abstract techniques. An example of complex identification by the use of indicators exclusively could be the identification of an airfield covered with lasting snow. The runway, taxiways, hardstands, and builtup area would be indicated by the forest clearings for these respective elements. The indicator elements need to be identified, recognized or detected as the specific case may be. The reliability of the presence determination of the indicator element and of the element which it indicates will vary with the respective case. Indicator analysis has acquired a state of disrepute because of use by individuals with inadequate skill; the indicators were of adequate reliability in spite of misapplication by the inadequately skilled extractor.

Environmental analysis is a technique by which the presence of a complex is determined primarily by an analysis of complexes and features exterior to the complex under question. Each type of complex is usually located in a restricted position with respect to its environment which consists of both natural complexes and cultural complexes. We might say in other words that the technique is to determine the type of complex which may be present within a given context of environment. Relatively little formalized development of environmental analysis techniques has been accomplished. It may be considered to be an association analysis technique of a higher level of abstraction, or a unit of much broader area coverage than just a single complex.

Environmental analysis maximizes the emphasis on determining the presence of the surrounding complexes by recognition and detection of component elements, thus with a minimum of image information. It is believed that this technique is essentially only for the more skilled extractors in order to obtain adequate probabilities of correct complex identification.

Integration analysis is a technique by which a complex is identified by using a combination of the other analysis techniques. The particular combination or combinations of techniques which may be used to identify a complex depend upon the nature of the respective complex. The integration analysis is in reality the technique which is usually employed by an extractor after he has acquired a minimum of operational experience. A maximized utilization of this technique is dependent upon the ingenuity of the extractor.

Integration analysis is too complex and too variable to discuss in great detail. A few elementary ideas will be mentioned. Environmental analysis may be used to determine types of complexes which could be present and not present at the given site. Indicator analysis might be used to determine the presence of diagnostic elements, association elements, layout elements and/or environmental elements. A complex might be identified by using a combination of diagnostic element analysis and layout analysis. For example, integration analysis would be especially applicable to what we might call fragment analysis where some components or elements of the unknown complex are obscured by partial cloud cover. Integration analysis is especially applicable to utilizing raw data from two or more different types of sensor system.

The more abstract extraction techniques place less exacting resolution requirements on the sensing-system. Some such techniques are considered to be as reliable as diagnostic element analysis; these are association analysis and integration analysis. In general, the more subtle the extraction technique and the less exacting the resolution requirements, the easier it would be to spoof the information system. However, the probability of spoofing would be greatly reduced by the employment of the more skilled extractor. The more abstract techniques are more difficult to communicate in training. Reference manuals compiled to utilize any one or all of these techniques would require much more skill to keep the organization and presentation simple, communicable and reliable. These techniques place more exacting requirements on the skills of the extractor.

The more abstract and subtle extraction techniques, layout analysis, association analysis, environmental analysis, indicator analysis, and integration analysis, usually provide slightly less precise information for problem analysis. There is greater emphasis on the skill and judgment of the operations analyst. However, the application of these more subtle extraction techniques provides significantly greater and more realistic information outputs than can be obtained from a reconnaissance system or from an information system. Such an increase in output is dependent upon the respective types of complexes, extraction techniques considered, and skills of the extractor.

Each problem must be analyzed on its own merits. In general the problems involve the analysis of a certain subject or subjects of interest, the probabilities of correct identification of these subjects or complexes, the information outputs that may be expected of reconnaissance systems and information system, and the operational problems associated with the subjects, data gathering, information extraction, data handling and information analysis systems. The analysis of a problem may require analysis of the subject, transfer characteristics of the sensing or data gathering system, definitive extraction techniques required to identify the subject, determination of the probabilities of correct subject identification by the alternative extraction techniques, operational procedures to maximize the output of evaluated information, etc.

Such analyses provide a systematic means to analyze any problem and the results can be presented in more definitive means, that is in quantitative form. It is important that definitive rather than ambiguous extraction techniques be incorporated. Some of the problems to which a contribution can be made are stated as questions, as follows: What procedures should be used to locate certain types of complexes from a mass of image data, within certain time limits, such as might be expected from an "open sky" program or a "sputnik" program? How little image information can I tolerate in order to identify certain complexes with certain probabilities? How can I increase information outputs to a significant degree without changing the information gathering system? How much must the ground resolution be changed to provide significantly greater information outputs? How much will I gain in information outputs by adding another specific type of sensing system? Will there be a significant difference in information outputs between two specific systems? In conclusion, consideration of fundamental extraction techniques assists in providing more definite results in the operations analysis of such problems.

*Determination of Sand Grain Sphericity by Stereo Photomicrography**

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An index property of particulate materials is their component shapes which may be described by analogy to geometric forms. Because sand grains tend to approach spheres in the course of time and wear, an expression for grain shapes is furnished by *sphericity*. It is the purpose of this paper to show how measurement of sand grain sphericity may be performed photogrammetrically.

Sphericity is a function of the relative lengths of particle intercepts and is measured according to the equation of Wadell (1932):

$$S = \sqrt[3]{\frac{V_p}{V_{cs}}}$$

where

S = sphericity;
V_p = particle volume;
V_{cs} = volume of circumscribing sphere.

A platy particle has a sphericity near zero whereas with a true sphere the value is unity. Values of sphericity are independent of the particular shape class into which the particle falls, thus particles with decidedly different appearances may have equal sphericity values. Also, sphericity is independent of *roundness* which measures the departure from angularity of outline. Examples A and B show different degrees of roundness but comparable values of sphericity.

Sphericity is not a significant index for water transported quartz particles smaller than 200 mesh (0.074 mm.). A film of water is omnipresent on these grains and protects them from attrition in transport; thus an angular and fresh appearance is preserved even after considerable transportation.

Data about the sphericity of sand deposits can be of service to the engineer and the geologist. A study of this sort can be helpful to the placer prospector for he can specify transporting agents and decide whether or not his specimens came from the traction load or the suspension load; this is often an important distinction. In addition, he can unravel age relations among stream terraces using the guide that, in general, the most nearly spherical grains have been the most travelled and are hence occupying the lowest (most recent) terraces. For the same reasons, sphericity studies can be of service to the glacial geologist or geomorphologist attempting to interpret the geomorphic history of an area. Geochemical prospecting can also be served by sphericity analyses, the results of studies helping to distinguish residual from transported soils and, as above, indicating the nature of the transportation. The petroleum geologist, interested in aquifer storage potential and permeability can make more accurate pro-

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