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Glossary and Index to Remotely Sensed Image Pattern Recognition Concepts*

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Abstract—The purpose of the glossary is to state in the simplest possible way the general meaning or word usage for many of the terms in image pattern recognition. There is no intent to provide definitive statements for terms such as "resolution" but rather only statements about the general nature of what resolution is. There is no intent to provide mathematical formulas involving integrals or derivatives in any of the statements. Those who need the mathematics can get it from technical papers or texts.

The glossary is designed to be read by those generally unfamiliar with the area and provide for them an overall perspective. The organization approaches that of programmed learning material and can be smoothly (I hope) read from beginning to end. Those needing to look up a specific term can do so via the index.

There is some overlap of terms in this glossary with those glossaries or definitions in radiometry and aerial photography. There is no intent that the way the terms are described here replace the way they are described in those glossaries and definitions. The overlap is provided here so that the reader can get a perspective of a cluster of terms frequently used in our field. The perspective is intended to start from what the image concept is through the recording of an image by some sensor, the possible conversion of image format and the simple analog or more complex digital processing which must be done on the imagery. In short, the perspective is one of image pattern recognition.

1. An *Image* is a spatial representation of an object, scene, or another image. It can be real or virtual as in optics. In pattern recognition, image usually means a recorded image such as a photograph, map, or picture. It may be abstractly thought of as a continuous function I of two variables defined on some bounded region of a plane. When the image is a photograph, the range of the function I is the set of grey shades usually considered to be normalized to the interval $[0, 1]$. The grey shade located at spatial coordinate (x, y) is denoted by $I(x, y)$ and is usually proportional to the radiant energy in the electromagnetic band to which the photographic sensor is sensitive. When the image is a map, the range of the function I is a set of symbols or colors, and the symbol or color located at spatial coordinate (x, y) is denoted by $I(x, y)$. A recorded image may be in photographic, video signal, or digital format.

2. The *grey shade* or *grey tone* is a number or value assigned to a position (x, y) on an image. The number is proportional to the integrated output, reflectance, or transmittance of a small area, usually called a resolution cell or pixel, centered on the position (x, y). The grey shade can be measured as or expressed in any one of the following ways:

(1) transmittance
(2) reflectance
(3) a coordinate of the ICI color coordinate system

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(4) a coordinate of the tristimulus value color coordinate system
(5) brightness
(6) radiance
(7) luminance
(8) density
(9) voltage
(10) current.

3. A *photograph* is a "hard copy" pictorial record of an image formed by a sensor. The photograph is usually recorded on some type of phososensitive emulsion. It can be either reflective, as is a paper print, or transmissive, as is a transparency. It is usually two-dimensional and its reflectance or transmittance, (either monochromatic or polychromatic) varies as a function of position. If it is a multi-colored image (polychromatic), it can be either natural color where the colors are similar to the original, or false color where the colors of the photograph are radically different from the original. The sensor used to form the image may be any type such as an optical camera with or without spectral filtration, infrared optical–mechanical scanners, TV systems, radars, or sonic sensors, etc. The type of sensor recording the image and spectral region the sensor is sensitive to, should always be indicated when referring to a photograph.

4. A *map* is a representation, of physical and/or cultural features (natural, artificial or both) of a region (such as the sky) or a surface such as that of the earth or a planet. It indicates by a combination of symbols and colors those regions having designated category identifications. Very often ground truth and/or decision rule category assignments are displayed by maps. A photograph with limited symbolism and annotation is often called a *photo-map*.

5. The *radiant intensity* of a point object is a measure of the radiant power per steradian radiated or reflected by an object. In general, radiant intensity is a function of the nature of the object, the viewing angle, spectral wavelength and band-width.

6. The *reflectance or reflection coefficient* is the ratio of the energy per unit time per unit area (radiant power density) reflected by the object to the energy per unit time per unit area incident on the object. In general, reflectance is a function of the incident angle of the energy, viewing angle of the sensor, spectral wavelength and bandwidth, and the nature of the object.

7. The *transmittance* or *transmittance coefficient* is the ratio of the energy per unit time per unit area (radiant power density) transmitted through the object to the energy per unit time per unit area incident on the object. In general, transmittance is a function of the incident angle of the energy, viewing angle of the sensor, spectral wavelength and bandwidth, and the nature of the object.

8. The *density* of an (x, y) position on a photograph is a measure of the light absorbing capability of the silver or dye deposited on that position. It is defined by the logarithm of the position's reciprocal transmittance. The density measured should be specified as to whether it is specular or diffuse.

9. *Densitometry* is the field devoted to the measurement of optical image densities on film or print grey shades usually caused by the absorption or reflection of light by developed photographic emulsion.

10. A *densitometer* is a device used to measure the average image density of a small area of specified size on a photographic transparency or print. The measurement may be a

meter reading or an electronic signal. When the small area is smaller than a few hundred microns square, the instrument is called a *micro-densitometer*.

11. The *contrast* for a point object against its background can be measured by: (1) its *contrast ratio*, which is the ratio between the higher of object transmittance or background transmittance to the lower of object transmittance or background transmittance; (2) its *contrast difference*, which is the difference between the higher density of object or background to the lower density of object or background; (3) its *contrast modulation*, which is the difference between the darker of object or background grey shade and the lighter of object or background grey shade divided by the sum of object grey shade and background grey shade.

12. *Resolution* is a generic term which describes how well a system, process, component or material, or image can reproduce an isolated object or separate closely spaced objects or lines. The *limiting resolution*, *resolution limit* or *spatial resolution* is described in terms of the smallest dimension of the target or object that can just be discriminated or observed. Resolution may be a function of object contrast, spatial position as well as element shape (single point, number of points in a cluster, continuum, or line etc.).

13. The *resolving power* of an imaging system, process, component or material is a measure of its ability to image closely spaced objects. The most common practice in measuring resolving power is to image a resolving power target composed of lines and spaces of equal width. Resolving power is usually measured at the image plane in line pairs per millimeter, i.e. the greatest number of lines and spaces per millimeter that can just be recognized. This threshold is usually determined by using a series of targets of decreasing size and basing the measurement on the smallest one in which all lines can be counted. In measuring resolving power the nature of the target (number of lines and their aspect ratio), its contrast and the criteria for determining the limiting resolving power *must be* specified.

14. *Acutance* is a measure of the sharpness of edges in a photograph or image. It is defined for any edge by the average squared rate of change of the density across the edge divided by the total density difference from one side of the edge to the other side of the edge.

15. The *spread function* of an image system, process, component, or material describes the resulting spatial distribution of grey shade when the input to the system is some well defined object much smaller than the width of the spread function. If the input to the system is a line, the spread function is called the *line spread function*. If the input to the system is a point, the spread function is called the *point spread function*.

16. The *Modulation Transfer Function* of an imaging system or component measures the spatial frequency modulation response of the system or component. As an imaging system or component processes or records an image, the contrast modulation of the processed or recorded image is different from the input image. In fact, there is always a spatial frequency beyond which the contrast modulation of the processed or recorded (output) image is smaller (worse) than the contrast modulation of the input image. The modulation transfer function can be thought of as a curve indicating, for each spatial frequency, the ratio of the contrast modulation of the output image to the contrast modulation of the input image. It is formally defined as the magnitude of the Fourier transform of the line spread function of the imaging system or component.

17. A *resolution cell* is the smallest most elementary areal constituent of grey shades considered by an investigator in an image. A resolution cell is referenced by its spatial coordinates. The resolution cell or formations of resolution cells can sometimes constitute the basic unit for pattern recognition of image format data.

18. A *digital image*, or *digitized image*, or *digital picture function* of an image is an image in digital format and is obtained by partitioning the area of the image into a finite two-dimensional array of small uniformly shaped mutually exclusive regions, called resolution cells, and assigning a "representative" grey shade to each such spatial region. A digital image may be abstractly thought of as a function whose domain is the finite two-dimensional set of resolution cells and whose range is the set of grey shades.

19. A *picture element* or *pixel* or *pel* is a pair whose first member is a resolution cell and whose second member is the grey shade assigned by the digital image to that resolution cell. Sometimes picture element, pixel, or pel refer only to the grey shade or grey shade n-tuple in a resolution cell.

20. A *multi-image* is a set of images, each taken of the same subject at different times, or from different positions, or with different sensors, or at different electromagnetic frequencies, or with different polarizations. Although there is a high degree of information redundancy between images in a multi-image set, each image usually has information not available in any one of or combinations of the other images in the set.

21. A *multi-digital image* is a multi-image in digital form. It can be, for example, a set of digital images obtained from the images in a multi-image. A multi-digital image is often called a multi-image for short when it is understood from context that digital images are involved.

22. A *flying spot scanner* is a device used to rapidly convert image data from photographic format to electronic video signal format. Normally, the scanner directs an electron beam across the face of a cathode ray tube (CRT) in a TV-like raster. The photographic transparency is placed in front of the CRT (either directly or through some optics) and the light coming from the CRT is passed through it. The modulated light beam is detected by a photomultiplier or other photo detector and amplified to a usable video signal level.

23. A *scanning densitometer* is a device used to convert image data from transparency photographic format to electronic video signal format. Usually, the photographic transparency is placed on a glass cylinder which rotates and slowly translates. A fine beam of light is focused on the transparency, passed through it, and is detected by a photo-multiplier where it is amplified to a usable video signal. The scanning densitometer is a much slower conversion device than the flying spot scanner. However, this disadvantage is compensated by its fine resolution capability of a few microns.

24. The *vidicon* is an imaging vacuum tube having a photosensitive surface and is a means of converting image data from instantaneous radiance format to electronic video signal format. The scene being viewed is imaged on the photosensitive surface which can be scanned by an electron beam generating a signal whose amplitude corresponds to the radiant intensity focused on the surface at each point. This signal is called a *video signal* and may be amplified to any desired level.

25. A *video image* is an image in electronic signal format capable of being displayed on a cathode ray tube screen. The video signal is generated from devices like a vidicon or flying spot scanner which converts an image from photographic form to video signal form by scanning it line by line. The video signal itself is a sequence of signals, the ith signal representing the ith line of the scanned image.

26. *Registering* is the translation–rotation alignment process by which two images of like geometries and of the same set of objects are positioned coincident with respect to one another so that corresponding elements of the same ground area appear in the same place on the registered images. In this manner, the corresponding grey shades of the two images

at any (x, y) coordinate or resolution cell will represent the sensor output for the same object over the full image frame being registered.

27. *Congruencing* is the process by which two images of a multi-image set are transformed so that the size and shape of any object on one image is the same as the size and shape of that object on the other image. In other words, when two images are congruenced, their geometries are the same and they coincide exactly.

28. *Rectifying* is a process by which the geometry of an image area is made planimetric. For example, if the image is taken of an equally spaced rectangular grid pattern, then the rectified image will be an image of an equally spaced rectangular grid pattern. Rectification does not remove relief distortion.

29. *Change detection* is the process by which two images may be compared, resolution cell by resolution cell, and an output generated whenever corresponding resolution cells have different enough grey shades or grey shade n-tuples.

30. An *optical color combiner* is an instrument which produces "false" or "true" color images by linearly combining a few black and white transparencies of the same scene. The transparencies are usually obtained from multi-spectral, multi-band, or time-sequential photography. The transparencies are placed in projectors which are all focused and registered on the same screen and which have various color filters placed in front of their lenses. The viewing brightness of the projector's lamp in each projector can be changed independently thereby changing chromaticity balance. An optical color combiner is sometimes called an *additive color display*.

31. An *electronic color combiner* is an instrument which produces a "false" color image by linearly combining video signals of images of the same scenes. The images are usually obtained from multi-spectral, multi-band, or time-sequential photography. If the original image format is photographic, then the image format is changed from photographic to video signal format by synchronized vidicons or flying spot scanners. The resulting video signals are linearly combined through a matrix multiplier circuit, and the three linearly combined signals then drive the color gun of a color TV tube. An electronic color combiner usually has greater versatility for congruencing or registering than an optical color combiner.

32. *Level slicing* or *density slicing* or *thresholding* is an operation performed by an instrument (usually electronic) called a level slicer to change one or more a grey scale images to one binary image.

33. The *level slicer, density slicer* or *thresholder* is an instrument (usually electronic) which takes a single or multi-image as an input and produces a binary image for an output. A binary "one" is produced on the output image whenever the grey shades on each of the input images lie within the independently set minimum and maximum thresholds. A set of N input images would, therefore, require a setting N minimum and N maximum levels.

34. A *figure* F, or a *subimage* F in a continuous or digital image I is any function F whose domain is some subset A of the set of spatial coordinates or resolution cells, whose range is the set G of grey shades, and which is defined by $F(x, y) = I(x, y)$ for any (x, y) belonging to A.

35. A figure F is *connected* if there is a path between any two spatial coordinates or resolution cells contained in the domain of F. More precisely, F is connected if for each pair of spatial coordinates (x, y) and (u, v) belonging to the domain of F, there exists some sequence $\langle (a_1, b_1), (a_2, b_2), \ldots, (a_m, b_m) \rangle$ of spatial coordinates belonging to the domain

of F such that $(x, y)=(a_1, b_1), (u, v)=(a_m, b_m)$, and (a_i, b_i) and (a_{i+1}, b_{i+1}) are sufficiently close neighboring coordinates, $i = 1, 2, \ldots, m-1$.

36. A figure F is *convex* if the domain of F contains the line segment which joins any pair of spatial coordinates in the domain of F.

37. A *discrete tonal feature* on a continuous or digital image is a connected set of spatial coordinates or resolution cells all of which have the same or almost the same grey shade.

38. *Texture* is concerned with the spatial distribution of the grey shades and discrete tonal features. When a small area of the image has little variation of discrete tonal features, the dominant property of that area is grey shade. When a small area has wide variation of discrete tonal features, the dominant property of that area is texture. There are three things crucial in this distinction: (1) the size of the small areas, (2) the relative sizes of the discrete tonal features, and (3) the number of distinguishable discrete tonal features.

39. *Quantizing* is the process by which each grey shade in an image of photographic, video, or digital format is assigned a new value from a given finite set of grey shade values. There are three often used methods of quantizing:

(1) in *equal interval quantizing* or *linear quantizing*, the range of grey shades from maximum grey shade to minimum grey shade is divided into contiguous intervals each of equal length, and each grey shade is assigned to the quantized class which corresponds to the interval within which it lies;

(2) in *equal probability quantizing*, the range of grey shades is divided into contiguous intervals such that after the grey shades are assigned to their quantized class there is an equal frequency of occurrence for each quantized grey shade in the quantized digital image or photograph; equal probability quantizing is sometimes called *central stretching*;

(3) in *minimum variance quantizing*, the range of grey shades is divided into contiguous intervals such that the weighted sum of the variance of the quantized intervals is minimized. The weights are usually chosen to be the grey shade interval probabilities which are computed as the proportional area on the photograph or digital image which have grey shades in the given interval.

40. A *quantizer* is an instrument which does quantizing. The quantizer has three functional parts. The first part allows the determining and/or setting of the quantizing intervals, the second part is a level slicer which indicates when a signal is in any quantizing interval, and the third part takes the binary output from the level slicers and either codes it to some binary code or converts it to some analog signal representing quantizing interval centers or means.

41. The simplest and most practical *unit* to observe and measure in the pattern recognition of image data is often the basic picture element (the grey shade or the grey shade n-tuple in its particular resolution cell). This is what makes pattern recognition so hard sometimes for the objects requiring analysis or identification are not simple picture elements but are often complex spatial formations of picture elements such as houses, roads, forest, etc.

42. A *measurement n-tuple* or *measurement pattern* or *pattern* or *measurement vector* is the ordered n-tuple of measurements obtained of a unit under observation. Each component of the n-tuple is a measurement of a particular quality, property, feature, or characteristic of the unit. In image pattern recognition, the units are usually picture elements or simple formations of picture elements and the measurement n-tuples are the corresponding grey shades, grey shade n-tuples, or formations of grey shade n-tuples.

43. The *range set* R_i for the ith sensor which produces the ith image in the multi-image set, is the set of all measurements which can be produced by the ith sensor. Simply, it is the set of all grey shades which could possibly exist on the ith image.

44. The *Cartesian product* of two sets A and B, denoted by $A \times B$, is the set of all ordered pairs where the first component of the pair is some element from the first set and the second component of the pair is some element from the second set. The Cartesian product of N sets can be inductively defined in the usual fashion.

45. *Measurement space* is a set large enough to include in it the set of all possible measurement n-tuples which could be obtained by observing physical attributes of some set of units. When the units are single resolution cells or picture elements, measurement space M is the Cartesian product of the range sets of the sensors; $M = R_1 \times R_2 \times \cdots \times R_n$.

46. Each unit is assumed to be of one and only one given type. The set of types is called the set of *pattern classes* or *categories* C, each type being a particular category. The categories are chosen specifically by the investigator as being the ones of interest to him.

47. A *feature* or *feature pattern* or *feature n-tuple* or *pattern feature* is a n-tuple or vector with (a small number of) components which are functions of the initial measurement pattern variables or some subsequence of the measurement n-tuples. Feature n-tuples or vectors are designed to contain a high amount of information relative to the discrimination between units of the types of categories in the given category set. Sometimes the features are predetermined and other times they are determined at the time the pattern discrimination problem is being solved. In image pattern recognition, features often contain information relative to grey shade, texture, shape or context.

48. *Feature space* is the set of all possible feature n-tuples.

49. *Feature selection* is the process by which the features to be used in the pattern recognition problem are determined. Sometimes feature selection is called *property selection.*

50. *Feature extraction* is the process in which an initial measurement pattern or some subsequence of measurement patterns is transformed to a new pattern feature. Sometimes feature extraction is called *property extraction.*

51. The word *pattern* can be used in three distinct senses:

(1) as measurement pattern;

(2) as feature pattern; and

(3) as the dependency pattern or patterns of relationships among the components of any measurement n-tuple or feature n-tuple derived from units of a particular category and which are unique to those n-tuples, that is, they are dependencies which do not occur in any other category.

52. A *signature* is the observable or characteristic measurement or feature pattern derived from units of a particular category. A category is said to have a signature only if the characteristic pattern is highly representative of the n-tuples obtained from units of that category. Sometimes a signature is called a *prototype pattern.*

53. A *data sequence* $S_d = \langle d_1, d_2, \ldots, d_J \rangle$ is a sequence of patterns derived from the measurement patterns or features of some sequence of observed units. d_1 is the pattern associated with the first unit; d_2 is the pattern associated with the second unit; and d_J is the pattern associated with the Jth unit.

54. A *decision rule* f usually assigns one and only one category to each observed unit on the basis of the sequence of measurement patterns in the data sequence S_d or in the corresponding sequence of feature patterns.

55. A *simple decision rule* is a decision rule which assigns a unit to a category solely on the basis of the measurements or features associated with the unit. Hence, the units are treated independently and the decision rule f may be thought of as a function which assigns one and only one category to each pattern in measurement space or to each feature in feature space.

56. A *compound decision rule* is a decision rule which assigns a unit to a category on the basis of some non-trivial subsequence of measurement patterns in the data sequence or in the corresponding sequence of feature patterns. A compound decision rule is not a simple decision rule.

57. Provision can be made for the decision rule to *reserve judgement* or to *defer assignment* if the pattern is too close to the category boundary in measurement or feature space. With this provision, a deferred assignment is an assignment to the category of "reserved judgement."

58. A *category identification sequence* or *ground truth* $S_c = \langle c_1, c_2, \ldots, c_J \rangle$ is a sequence of category identifications obtained from some sequence of observed units. c_1 is the category identification of the first unit; c_2 is the category identification of the second unit; and c_J is the category identification of the Jth unit.

59. A *training sequence* is a set of two sequences: (1) the data sequence and (2) a corresponding category identification sequence (sometimes called ground truth). The training sequence is used to estimate the category conditional probability distributions from which the decision rule is constructed.

60. The *conditional probability* of a measurement or feature n-tuple d given category c is denoted by $P_c(d)$, or by $P(d/c)$, and is defined as the relative frequency or proportion of times the n-tuple d is derived from a unit whose true category identification is c.

61. A *distribution-free* or *non-parametric decision rule* is one which makes no assumptions about the functional form of the conditional probability distribution of the patterns given the categories.

62. A simple *maximum likelihood decision rule* is one which treats the units independently and assigns a unit u having pattern measurement or features d to that category c whose units are most probable to have given rise to pattern or feature vector d, that is, such that the conditional probability of d given c, $P_c(d)$, is highest.

63. A simple *Bayes decision rule* is one which treats the units independently and assigns a unit u having pattern measurements or features d to the category c whose conditional probability, $P_d(c)$, given measurement d, is highest.

64. Let $\langle u_1, u_2, \ldots, u_J \rangle$ be a sequence of units with corresponding data sequence $\langle d_1, d_2, \ldots, d_J \rangle$ and known category identification sequence $\langle c_1, c_2, \ldots, c_J \rangle$. A simple *nearest neighbor decision rule* is one which treats the units independently and assigns a unit u of unknown identification and with pattern measurements or features d to category c_j where d_j is that pattern closest to d by some given metric or distance function.

65. A *discriminant function* $f_i(d)$ is a scalar function, whose domain is usually measurement space and whose range is usually the real numbers. When $f_i(d) \geq f_k(d)$, $k = 1, 2, \ldots, K$, then the decision rule assigns the ith category to the unit giving rise to pattern d.

66. A *linear discriminant function* f is a discriminant function of the form

$$f(d) = b + \sum_{j=1}^{n} a_j \delta_j \text{ where } d = (\delta_1, \delta_2, \ldots, \delta_n).$$

67. A *decision boundary* between the ith and kth categories is a subset H of patterns in measurement space M defined by

$$H = \{d \in M | f_i(d) = f_k(d)\},$$

where f_i and f_k are the discriminant functions for the ith and kth categories.

68. A *hyperplane decision boundary* is the special name given to decision boundaries arising from the use of linear discriminant functions.

69. A *linear decision rule* is a simple decision rule which usually treats the units independently and makes the category assignments using linear discriminant functions. The decision boundaries obtained from linear decision rules are hyperplanes.

70. The *pattern discrimination* problem is concerned with how to construct the decision rule which assigns a unit to a particular category on the basis of the measurement pattern(s) in the data sequence or on the basis of the feature pattern(s) in the data sequence.

71. *Pattern identification* is the process in which a decision rule is applied. If $S_u = \langle u_1, u_2, \ldots, u_J \rangle$ is the sequence of units to be observed and identified, and if $S_d = \langle d_1, d_2, \ldots, d_J \rangle$ is the corresponding data sequence of patterns, then the pattern identification process produces a category identification sequence $S_c = \langle c_1, c_2, \ldots, c_J \rangle$ where c_i is the category in C to which the decision rule assigns unit u_i on the basis of the J patterns in S_d. In general, each category in S_c can be assigned by the decision rule as a function of all the patterns in S_d. Sometimes pattern identification is called "*pattern classification*" or "*classification*".

72. A *cluster* is a homogeneous group of units which are very "like" one another. "Likeness" between units is usually determined by the association, similarity, or distance between the measurement patterns associated with the units.

73. A *cluster assignment function* is a function which assigns each observed unit to a cluster on the basis of the measurement pattern(s) in the data sequence or on the basis of their corresponding features. Sometimes the units are treated independently; in this case the clustering assignment function can be considered as a transformation from measurement space to the set of clusters.

74. The *pattern classification* problem is concerned with constructing the cluster assignment function which groups similar units. Pattern classification is synonymous with *numerical taxonomy* or *clustering*.

75. The *cluster identification* process is the process in which the cluster assignment function is applied to the sequence of observed units thereby yielding a cluster identification sequence.

76. A *misidentification*, or *misdetection*, or *type I error* occurs for category c_i if a unit whose true category identification is c_i is assigned by the decision rule to category c_k, $k \neq i$. A misidentification error is often called an *error of omission*.

77. A *false identification*, or *false alarm*, or *type II error* occurs for category c_i if a unit whose true category identification is c_k, $k \neq i$, is assigned by the decision rule to category c_i. A false identification error is often called an *error of commission*.

78. A *prediction sequence*, or *test sequence*, or a *generalization sequence* is a set of two sequences: (1) a data sequence (whose corresponding true category identification sequence may be considered to be unknown to the decision rule) and (2) a corresponding category identification sequence determined by the decision rule assignment. By comparing the category identification sequence determined by the decision rule assignment with the

category identification sequence determined by the ground truth, the misidentification rate and the false identification rate for each category may be estimated.

79. A *confusion matrix* or *contingency table* is an array of probabilities whose rows and columns are both similarly designated by category label and which indicates the probability of correct identification for each category as well as the probability of type I and type II errors. The (ith, kth) element P_{ik} is the probability that a unit has true category identification c_i; and is assigned by the decision rule to category c_k.

80. A unit is said to be *detected* if the decision rule is able to assign it as belonging only to some given subset A of categories from the set C of categories. To detect a unit does not imply that the decision rule is able to identify the unit as specifically belonging to one particular category.

81. A unit is said to be *recognized, identified, classified, categorized* or *sorted* if the decision rule is able to assign it to some category from the set of given categories. In military applications, there is a definite distinction between recognize and identify. Here, for a unit to be recognized, the decision rule must be able to assign it to a type of category, the type having included within it many subcategories. For a unit to be identified, the decision rule must be able to assign it not only to a type of category but also to the subcategory of the category type. For example, a small area ground patch may be recognized as containing trees, which may be specifically identified as apple trees.

82. A unit is said to be *located* if specific coordinates can be given for the units physical location.

83. A unit is said to be *acquired* if it can be located and recognized.

84. A *target* is one type of category used in the pattern recognition of image data. It usually occupies some relatively small area on the image and has a unique or characteristic set of attributes. It has a high *a priori* interest to the investigator.

85. *Target discrimination* is the process by which decision rules for targets (small area extensive categories) are constructed.

86. *Target identification* or *target recognition* is the process by which targets contained within image data are identified by means of a decision rule.

87. An *image transformation* is a function or operator which takes an image for its input and produces an image for its output. The domain of the transform operator is often called the spatial domain. The range of the transform operator is often called the transformed domain. Some transformations have spatial and transform domains of entirely different character. For these transforms, the image in the spatial domain may appear entirely different from and have a different interpretation from the image in the transformed domain. Specific examples of these kinds of transformations are the Fourier, Hadamard, and Karhunen–Loéve transformations. Other transformations have spatial and transform domain of similar character. For these transformations, the image in the transformed domain may appear similar to the image of the spatial domain. These types of transformations are often called spatial filters.

88. A *spatial filter* is an image transformation, usually a one-one operator used to lessen noise or enhance certain characteristics of the image. For any particular (x, y) coordinate on the transformed image, the spatial filter assigns a grey shade on the basis of the grey shades of a particular spatial pattern near the coordinates (x, y).

89. A *linear spatial filter* is a spatial filter for which the grey shade assignment at coordinates (x, y) in the transformed image is made by some weighted average (linear combination) of grey shades located in a particular spatial pattern around coordinates (x, y) of the domain image. The linear spatial filter is often used to change the spatial

frequency characteristics of the image. For example, a linear spatial filter which emphasizes high spatial frequencies will tend to sharpen the edges in an image. A linear spatial filter which emphasizes the low spatial frequencies will tend to blur the image and reduce salt and pepper noise.

90. *Template matching* is an operation which can be used to find out how well two photographs or images match one another. The degree of matching is often determined by cross-correlating the two images or by evaluating the sum of the squared corresponding grey shade differences. Template matching can also be used to best match a measurement pattern with a prototype pattern.

91. *Matched filtering* is a template matching operation done by using the magnitude of the cross-correlation function to measure the degree of matching.

92. In pattern recognition problems such as target discrimination, for which the category of interest is some specific formation of resolution cells with characteristic shape or tone–texture composition, the problem of pattern segmentation may occur. *Pattern segmentation* is the problem of determining which regions or areas in the image constitute the patterns of interest, i.e. which resolution cells should be included and which excluded from the pattern measurements.

93. *Screening* is the operation of separating the uninteresting photographs or images from those photographs containing areas of potential interest.

94. *Preprocessing* is an operation applied before pattern identification is performed. Preprocessing produces, for the categories of interest, pattern features which tend to be invariant under changes such as translation, rotation, scale, illumination levels, and noise. In essence, preprocessing converts the measurements patterns to a form which allows a simplification in the decision rule. Preprocessing can bring into registration, bring into congruence, remove noise, enhance images, segment target patterns, detect, center, and normalize targets of interest.

95. *Image compression* is an operation which preserves all or most of the information in the image and which reduces the amount of memory needed to store an image or the time needed to transmit an image.

96. *Image restoration* is a process by which a degraded image is restored to its original condition. Image restoration is possible only to the extent that the degradation transform is mathematically invertible.

97. *Image enhancement* is any one of a group of operations which improve the detectability of the targets or categories. These operations include, but are not limited to, contrast improvement, edge enhancement, spatial filtering, noise suppression, image smoothing, and image sharpening.

98. *Image processing* encompasses all the various operations which can be applied to photographic or image data. These include, but are not limited to, image compression, image restoration, image enhancement, preprocessing, quantization, spatial filtering, and other image pattern recognition techniques.

99. *Interactive Image Processing* refers to the use of an operator or analyst at a console with a means of assessing, preprocessing, feature extracting, classifying, identifying and displaying the original imagery or the processed imagery for his subjective evaluation and further interactions.

100. *Pattern recognition* is concerned with, but not limited to, problems of: (1) pattern discrimination, (2) pattern classification, (3) feature selection, (4) pattern identification, (5) cluster identification, (6) feature extraction, (7) preprocessing, (8) filtering, (9) enhancement, (10) pattern segmentation, or (11) screening.

INDEX TO GLOSSARY OF REMOTELY SENSED IMAGE PATTERN RECOGNITION CONCEPTS