CLAIMS

What is claimed is:

1. A method for inspecting features in a part for defects, the method comprising:

a. generating Reference Data, by using either Computer Aided Design (CAD) data or by combining scans of one or multiple known good parts, the Reference Data used for generating parameters for inspecting parts,

b. creating one or more tolerance bands in the Reference Data, around each of one or more features to be inspected, such that when parts of acceptable tolerance are scanned for inspection, each scanned feature falls within a tolerance band defined by the corresponding tolerance bands in the Reference Data,

c. locating edge pixels, in the Reference Data, along a perimeter of each feature,

d. for each edge pixel thus located, creating a measurement vector that originates from the edge pixel and points toward an opposite side of the feature, the vector oriented perpendicular to or at a predetermined angle with respect to the perimeter thereby also indicating edge orientation and whose vector length is the distance to the edge pixel on the opposite side of the feature,

e. storing information representative of a vector length, vector orientation, starting edge pixel, and ending edge pixel coordinates for each measurement vector, the stored information defining measurement locations to be used to locate feature edges when the part is subsequently inspected,

f. defining a linear search range to be used to locate each starting and ending edge pixel for each measurement vector when the part is subsequently inspected,

i. with each linear search range having a search axis oriented in a same angular orientation as its corresponding measurement vector,

ii. limits of search in one direction along the search axis extending away from each edge pixel with a limit in that one direction extending to or beyond a boundary defined by a closest tolerance band to that edge pixel, and

iii. a limit in the other direction along the search axis, for that same edge pixel, being equal to or greater than a closest distance between the edge pixel lying along the measurement axis on the other side of the feature and its closest tolerance band,

g. storing corresponding search ranges for each expected starting edge pixel and ending edge pixel location,

h. moving each feature in the Reference Data to all positions within its tolerance band, and

i. for each position of the feature at each previously stored starting and ending pixel measurement location, searching for edge pixels of the feature within the specified search range, and

i. when an edge pixel is found on the feature,

A. computing a length of a measurement vector, as a length from that edge pixel found to the edge pixel on the opposite side of the feature, said length determined at the previously stored measurement angle, and

B. storing as an allowable outcome the computed length of a measurement vector associated with each measurement location, and

C. when a length of a measurement vector exceeds a maximum measurable value, storing a representation of this result as an allowable outcome,

ii. when an edge pixel is not found on the feature, storing a representation of this result as an allowable outcome,

j. storing for each spatially fixed measurement location, a minimum and maximum allowable vector dimension, and allowable representations thereof, corresponding to the plurality of positions of the feature within its tolerance band,

k. creating an Inspection Parameter List of stored parameters to be used for inspecting features on a part defined by the reference data, said list containing for each measurement vector, information representative of:

i. an allowable minimum and maximum vector length, or representations of vector length indicating when the measurement length exceeds a maximum measurable value, or that no edge pixel was found,

ii. vector orientation,

iii. search range, and

iv. starting edge pixel location and ending edge pixel location,

l. modifying each minimum and maximum allowable vector length in the Inspection Parameter List to allow for acceptable process variations during inspection of the part,

m. inspecting the part from a scanned image by, for each measurement location in the Inspection Parameter List,

i. searching for edges of a feature within the search ranges around the expected starting edge pixel and ending edge pixel locations specified in the Inspection Parameter List,

A. when an edge is found in the scanned image, performing a vector measurement at the measurement angle specified in the Inspection Parameter List,

B. when the length of the measurement vector exceeds a maximum measurable value, storing a representation of this result,

C. when an edge pixel is not found in the scanned image, storing a representation of this result,

ii. comparing a length of vector measurement to the allowable minimum and maximum length values, or allowable representations thereof, specified in the Inspection Parameter List, and

iii. reporting as a defect, vector lengths that are less than the allowable minimum length or a representation thereof or greater than the allowable maximum length or a representation thereof in the Inspection Parameter List.

2. The method of claim 1 further comprising:

computing edge pixel locations to sub-pixel accuracy using an edge finding filter, such as, but not limited to a Sobel or Prewitt type filter.

3. The method of claim 1 additionally comprising:

comparing the scanned image of the part to a reference image to find defects.

4. The method of claim 1 additionally comprising:

a. converting the CAD data to a grayscale image, and

b. convolving or processing the grayscale image through a two-dimensional filter to simulate blurring of imaging optics to make the Reference Data better match the scanned image.

5. The method of claim 1 in which the part contains conductors and insulators that can be distinguished from each other in a scanned camera image.

6. The method of claim 1 additionally comprising:

a. during inspecting of a part from a scanned image, for a plurality of measurement locations corresponding to the locations of features in the Reference Data, where a feature dependent measurement is to be computed,

i. searching for edge pixels of said feature in the scanned image, within the search ranges around the expected edge pixel locations specified in the Reference Data,

ii. presenting to a Feature Shape Processor for analysis, locations of edge pixels found associated with each feature, and then

b. using the Feature Shape Processor for further

i. measuring one or more feature dimensions, and measuring at least one of, a distance of found edge pixels to a predetermined expected shape, or a widest dimension, a narrowest dimension, or a center of the feature, and

ii. reporting as a defect measured feature dimensions that exceed predetermined values.

7. A method for performing automated metrology measurements on electronic parts to obtain statistical data such as, but not limited to, minimum, maximum, average, and standard deviation feature size, line width and space measurements computed for an entire part, sections of a part, each die on a part, or sections of each die on a part, the method comprising:

a. generating Reference Data, by using either Computer Aided Design (CAD) data or by combining scans of one or multiple known good parts, the Reference Data used for generating parameters for measuring parts,

b. creating one or more tolerance bands in the Reference Data, around each of one or more features to be measured, such that when parts of acceptable tolerance are scanned, each scanned feature falls within a tolerance band defined by the corresponding tolerance bands in the Reference Data,

c. locating edge pixels, in the Reference Data, along a perimeter of each feature,

d. for each edge pixel thus located, creating a measurement vector that originates from the edge pixel and points toward an opposite side of the feature, the vector oriented perpendicular to or at a predetermined angle with respect to the perimeter thereby also indicating edge orientation and whose vector length is the distance to the edge pixel on the opposite side of the feature,

e. storing information representative of a vector length, vector orientation, starting edge pixel, and ending edge pixel coordinates for each measurement vector, the stored information defining measurement locations to be used to locate feature edges when the part is subsequently measured,

f. defining a linear search range to be used to locate each starting and ending edge pixel for each measurement vector, when the part is subsequently measured,

i. with each linear search range having a search axis oriented in a same angular orientation as its corresponding measurement vector,

ii. limits of search in one direction along the search axis extending away from each edge pixel with a limit in that one direction extending to or beyond a boundary defined by a closest tolerance band to that edge pixel, and

iii. a limit in the other direction along the search axis, for that same edge pixel, being equal to or greater than a closest distance between the edge pixel lying

along the measurement axis on the other side of the feature and its closest tolerance band,

g. storing corresponding search ranges for each expected starting edge pixel and ending edge pixel location,

h. moving each feature in the Reference Data to all positions within its tolerance band, and for each position of the feature at each previously stored starting and ending pixel measurement location, searching for edge pixels of the feature within the specified search range, and

i. when an edge pixel is found on the feature,

A. computing a length of a measurement vector, as a length from that edge pixel found to the edge pixel on the opposite side of the feature, said length determined at the previously stored measurement angle, and

B. storing as an allowable outcome the length of a measurement vector associated with each measurement location, and

C. when a length of a measurement vector exceeds a maximum measurable value, storing a representation of this result as an allowable outcome

ii. when an edge pixel is not found on the feature, storing a representation of this result as an allowable outcome

i. storing for each spatially fixed measurement location, a minimum and maximum allowable vector dimension, and allowable representations thereof, corresponding to the plurality of positions of the feature within its tolerance band,

j. storing and indicating, in a Measurement Parameter List, edge pixel measurement locations for those vectors whose length does not change or only changes within a small defined minimal critical width tolerance as each feature is moved within its corresponding tolerance band, such vectors referred to as Critical Width Vectors,

k. when measuring features on a part, from a scanned image, for each Critical Width Vector, searching for the edge pixels of a feature within the search ranges around the specified starting and ending edge pixel measurement locations and computing a vector length measurement defined as the length between those two found edges,

l. computing, from those vector length measurements, statistical data as a function of feature type, with said statistical data computed over the entire part, or for sections of a part, or for different die on a part or sections within different die on the part, with a given feature type being represented by features of the same dimensions in the Reference Data,

m. the statistical data being computed for a feature type being at least one of a minimum, a maximum, an average, a standard deviation, or other statistical value, and

n. reporting said statistical data, to characterize the part or for process control.

8. The method of claim 7 further comprising:

computing edge pixel locations to sub-pixel accuracy using an edge finding filter, such as, but not limited to a Sobel or Prewitt type filter.

9. The method of claim 7 additionally comprising:

comparing the scanned image of the part to a reference image to find defects.

10. The method of claim 7 additionally comprising:

a. converting the CAD data to a grayscale image, and

b. convolving or processing the grayscale image through a two-dimensional filter to simulate blurring of imaging optics to better match the Reference Data to the scanned image.

11. The method of claim 7 in which the part contains conductors and insulators that can be distinguished from each other in a scanned camera image.

12. The method of claim 7 additionally comprising:

a. during inspecting of a part from a scanned image, for a plurality of measurement locations corresponding to the locations of features in the Reference Data, where a feature dependent measurement is to be computed,

i. searching for edge pixels of said feature in the scanned image, within the search ranges around the expected edge pixel locations specified in the Reference Data,

ii. presenting to a Feature Shape Processor for analysis, locations of edge pixels found associated with each feature, and

iii. the Feature Shape Processor then measuring one or more feature dimensions, and measuring at least one of a distance of found edge pixels to a predetermined expected shape, or a widest dimension, a narrowest dimension, or a center of the feature,

b. computing, from those feature dimensions, statistical data for features of the same shape and size in the Reference Data, with said statistical data computed over the entire part, or for sections of a part, or for different die on a part or sections within different die on the part, and

c. reporting said statistical data, to characterize the part or for process control.

13. The method of claim 1 additionally comprising:

a. storing and indicating, in said Inspection Parameter List, additional vectors whose length does not change or only changes within a small defined minimal critical width tolerance as each feature is moved within its corresponding tolerance band in the Reference Data, such vectors referred to as Critical Width Vectors,

b. when measuring features on a part, from a scanned image, for each Critical Width Vector, searching for the edge pixels of a feature within the search ranges around the specified starting and ending edge pixel measurement locations and computing a vector length measurement defined as the length between those two found edges,

c. computing, from those Critical Width vector length measurements, statistical data as a function of feature type, with said statistical data computed over the entire part, or for sections of a part, or for different die on a part or sections within different die on the part, with a given feature type being represented by features of the same dimensions in the Reference Data,

d. the statistical data being computed for a feature type being at least one of a minimum, a maximum, an average, and a standard deviation, statistical value, and

e. reporting said statistical data, to characterize the part or for process control.

14. A method for inspecting features in a part for defects, the method comprising:

a. locating Reference Data,

b. defining a tolerance band that specifies how much one or more features may spatially deviate from the Reference Data,

c. creating measurement vectors at fixed spatial locations around a perimeter of each feature,

d. each measurement vector representing a dimension of the feature in the Reference Data from a point on the perimeter to another point on the perimeter at a specified angle,

e. defining a linear search range around each fixed spatial location to enable finding of starting and ending points for each measurement vector,

f. each linear search range having a search axis oriented in a same angular orientation as its corresponding measurement vector,

g. for each feature to be inspected, moving the feature to a plurality of positions within the feature's tolerance band, and

h. for each position of the feature and at each previously created spatially fixed measurement location, searching for points along the perimeter of the feature within the defined linear search range, and

i. when a point is found,

A. measuring a vector dimension at the angle specified by the corresponding measurement vector, and

B. storing as allowable, the vector dimension, or a representation indicating when the measurement dimension exceeds a maximum measurable value,

ii. when no point is found, storing a representation of this result as allowable, and

i. storing for each spatially fixed measurement location, minimum and maximum allowable vector dimensions, and allowable representations thereof, corresponding to the plurality of positions of the feature within its tolerance band,

j. modifying each minimum and maximum allowable vector dimension, or representation thereof, by adding a variance to allow for acceptable process variations during inspection of the part,

k. when inspecting a part from a scanned image, for each measurement vector, within the defined linear search ranges for that vector, searching for a point along the perimeter of a feature, and

i. when a point is not located, producing a representation indicating no point on the perimeter is found,

ii. when a point is located, measuring a vector dimension at the angle specified for that vector and producing a representation indicating when the dimension exceeds a maximum measurable value

l. reporting as a defect, vector dimensions that are less than the minimum allowable vector dimension or representation thereof or greater than the maximum allowable vector dimension or representation thereof.

15. The method of claim 14 in which the location of points along the perimeter of a feature are computed to sub-camera pixel accuracy using an edge finding filter, such as, but not limited to a Sobel or Prewitt type filter.

16. The method of claim 14 additionally comprising:

comparing the scanned image of the part to a reference image to find defects.

17. The method of claim 14 additionally comprising:

a. converting Computer Aided Design (CAD) data to a grayscale image, and

b. convolving or processing the grayscale image through a two-dimensional filter to simulate blurring of imaging optics to thereby better match the Reference Data to the scanned image.

18. The method of claim 14 in which the part contains conductors and insulators that can be distinguished from each other in a scanned camera image.

19. The method of claim 14 additionally comprising:

a. during inspecting of a part from a scanned image, for a plurality of measurement locations corresponding to the locations of features in the Reference Data, where a feature dependent measurement is to be computed,

i. searching for edge pixels of said feature in the scanned image, within the search ranges around the expected edge pixel locations specified in the Reference Data,

ii. presenting to a Feature Shape Processor for analysis, locations of edge pixels found associated with each feature, and

iii. the Feature Shape Processor then measuring one or more feature dimensions, and measuring at least one of, a distance of found edge pixels to a predetermined expected shape, or a widest dimension, a narrowest dimension, or a center of the feature, and

b. reporting as a defect measured feature dimensions that exceed predetermined values.

20. A method for measuring features in a part, the method comprising:

a. locating Reference Data,

b. defining a tolerance band that specifies how much one or more features may spatially deviate from the Reference Data,

c. creating measurement vectors at fixed spatial locations around a perimeter of each feature,

d. each measurement vector representing a dimension of the feature in the Reference Data from a point on the perimeter to another point on the perimeter at a specified angle,

e. defining a linear search range around each fixed spatial location to enable finding of starting and ending points for each measurement vector,

f. each linear search range having a search axis oriented in a same angular orientation as its corresponding measurement vector,

g. for each feature to be measured, moving the feature to a plurality of positions within the feature's tolerance band, and

h. for each position of the feature and at each previously created spatially fixed measurement location, searching for points along the perimeter of the feature within the defined linear search range, and

i. when a point is found,

A. measuring a vector dimension at the angle specified by the corresponding measurement vector, and

B. storing as allowable, the vector dimension, or representation indicating when the measurement dimension exceeds a maximum measurable value,

ii. when no point is found, storing a representation of this result as being allowable,

i. storing for each spatially fixed measurement location, minimum and maximum allowable vector dimensions, and allowable representations thereof, corresponding to the plurality of positions of the feature within its tolerance band,

j. further storing and marking as Critical Dimension Vectors those measurement vectors whose dimension does not change, or only changes within a defined minimal critical dimensional tolerance, as each feature is moved within its corresponding tolerance band,

k. when measuring a part from a scanned image, for each Critical Dimension Vector,

i. within the defined linear search ranges for that vector, locating points along the perimeter of the feature, and

ii. for each such perimeter point located, measuring a vector dimension at the same angle as its corresponding measurement vector calculated from the Reference Data,

l. computing, from the Critical Dimension Vector measurements, statistical data as a function of feature type, with said statistical data computed over the entire part, or for sections of a part, or for different die on a part or sections within different die on the part, with a given feature type being represented by features of the same dimensions in the Reference Data,

m. the statistical data being computed for a feature type being at least one of a minimum, a maximum, an average, a standard deviation, or other statistical value, and

n. reporting said statistical data, to be used to characterize the part or for process control.

21. The method of claim 20 in which the location of points along the perimeter of a feature are computed to sub-camera pixel accuracy using an edge finding filter, such as, but not limited to a Sobel or Prewitt type filter.

22. The method of claim 20 additionally comprising:

comparing the scanned image of the part to a reference image to find defects.

23. The method of claim 20 additionally comprising:

a. converting Computer Aided Design (CAD) data to a grayscale image, and

b. convolving or processing the grayscale image through a two-dimensional filter to simulate blurring of imaging optics to thereby better match the Reference Data to the scanned image.

24. The method of claim 20 in which the part contains conductors and insulators that can be distinguished from each other in a scanned camera image.

25. The method of claim 20 additionally comprising:

a. during inspecting of a part from a scanned image, for a plurality of measurement locations corresponding to the locations of features in the Reference Data, where a feature dependent measurement is to be computed,

i. searching for edge pixels of said feature in the scanned image, within the search ranges around the expected edge pixel locations specified in the Reference Data,

ii. presenting to a Feature Shape Processor for analysis, locations of edge pixels found associated with each feature,

iii. the Feature Shape Processor then measuring one or more feature dimensions, including measuring at least one of a distance of found edge pixels to a predetermined expected shape, or a widest dimension, a narrowest dimension, or a center of the feature,

b. computing, from those feature dimensions, statistical data for features of the same shape and size in the Reference Data, with said statistical data computed over the entire part, or for sections of a part, or for different die on a part or sections within different die on the part, the statistical data being computed for at least one of, a minimum, a maximum, an average, and a standard deviation for the measured feature dimensions, and

c. reporting the statistical data, to be used to characterize the part or for process control.

26. The method of claim 14 additionally comprising:

a. further storing and indicating those measurement vectors, called Critical Width Vectors, whose dimension does not change, or only changes within a small defined minimal

critical dimensional tolerance, as each feature is moved within its corresponding tolerance band in the Reference Data, and

b. when measuring a part from a scanned image, for each Critical Dimension Vector,

i. within the search ranges for that vector, locating points along the perimeter of the feature, and

ii. at each such perimeter point located, measuring a vector dimension at the same angle as its corresponding measurement vector in the Reference Data,

c. computing from the vector dimension measurements, statistical data as a function of feature type, with said statistical data computed over the entire part, or for sections of a part, or for different die on a part or sections within different die on the part, with a given feature type being represented by features of the same dimensions in the Reference Data,

d. statistical data being computed for, but not limited to, minimum, maximum, average, and standard deviation feature sizes for different feature types, and

e. reporting said statistical data, to be used to characterize the part or for process control.