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(54) **SYSTEMS AND METHODS FOR MEASURING A LIKE-COLOR REGION OF AN OBJECT**

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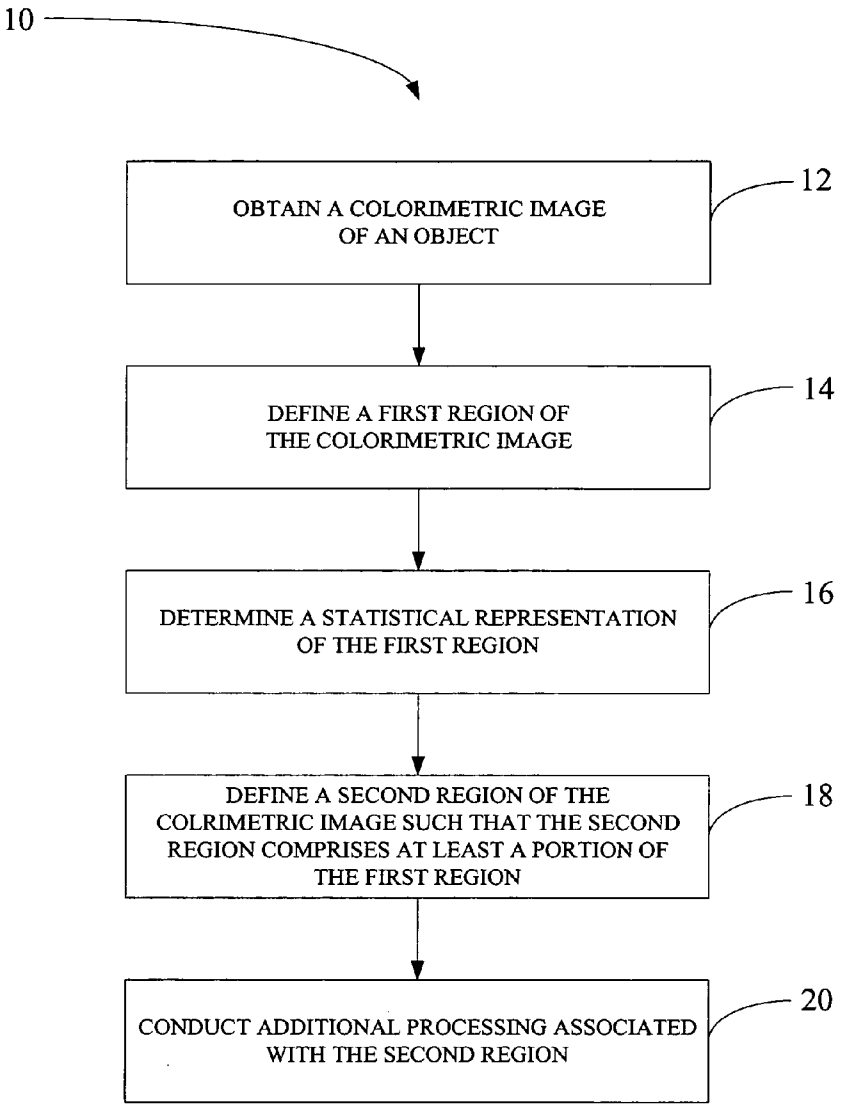
(57) **ABSTRACT**

A method for measuring a like-color region of an object. The method includes defining a first region of a colorimetric image of the object, determining a statistical representation of the first region based on a color metric, and defining a second region of the calorimetric image such that the second region comprises at least a portion of the first region.



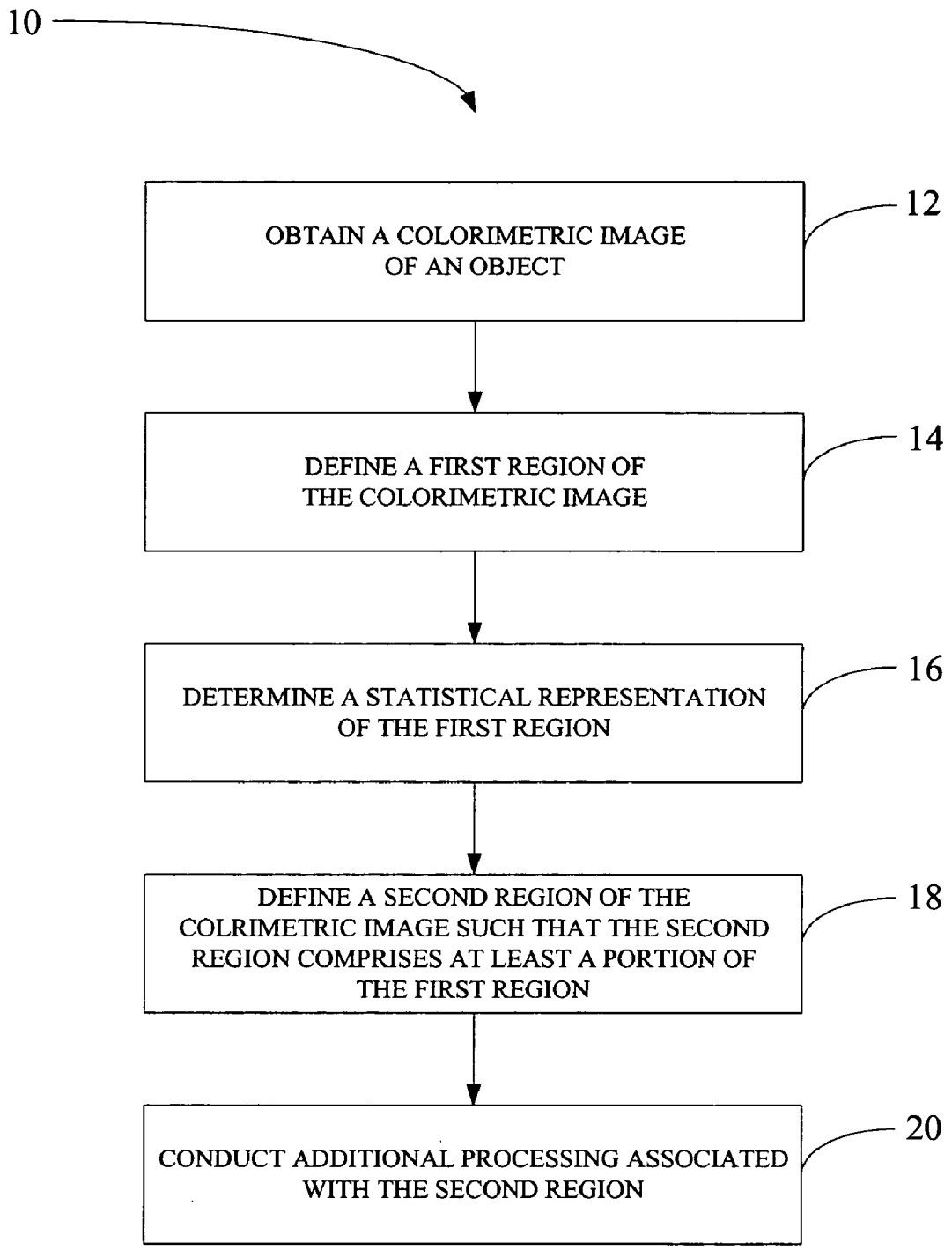

10
OBTAIN A COLORIMETRIC IMAGE OF AN OBJECT
12
DEFINE A FIRST REGION OF THE COLORIMETRIC IMAGE
14
DETERMINE A STATISTICAL REPRESENTATION OF THE FIRST REGION
16
DEFINE A SECOND REGION OF THE COLRIMETRIC IMAGE SUCH THAT THE SECOND REGION COMPRISES AT LEAST A PORTION OF THE FIRST REGION
18
CONDUCT ADDITIONAL PROCESSING ASSOCIATED WITH THE SECOND REGION
20

Figure 1

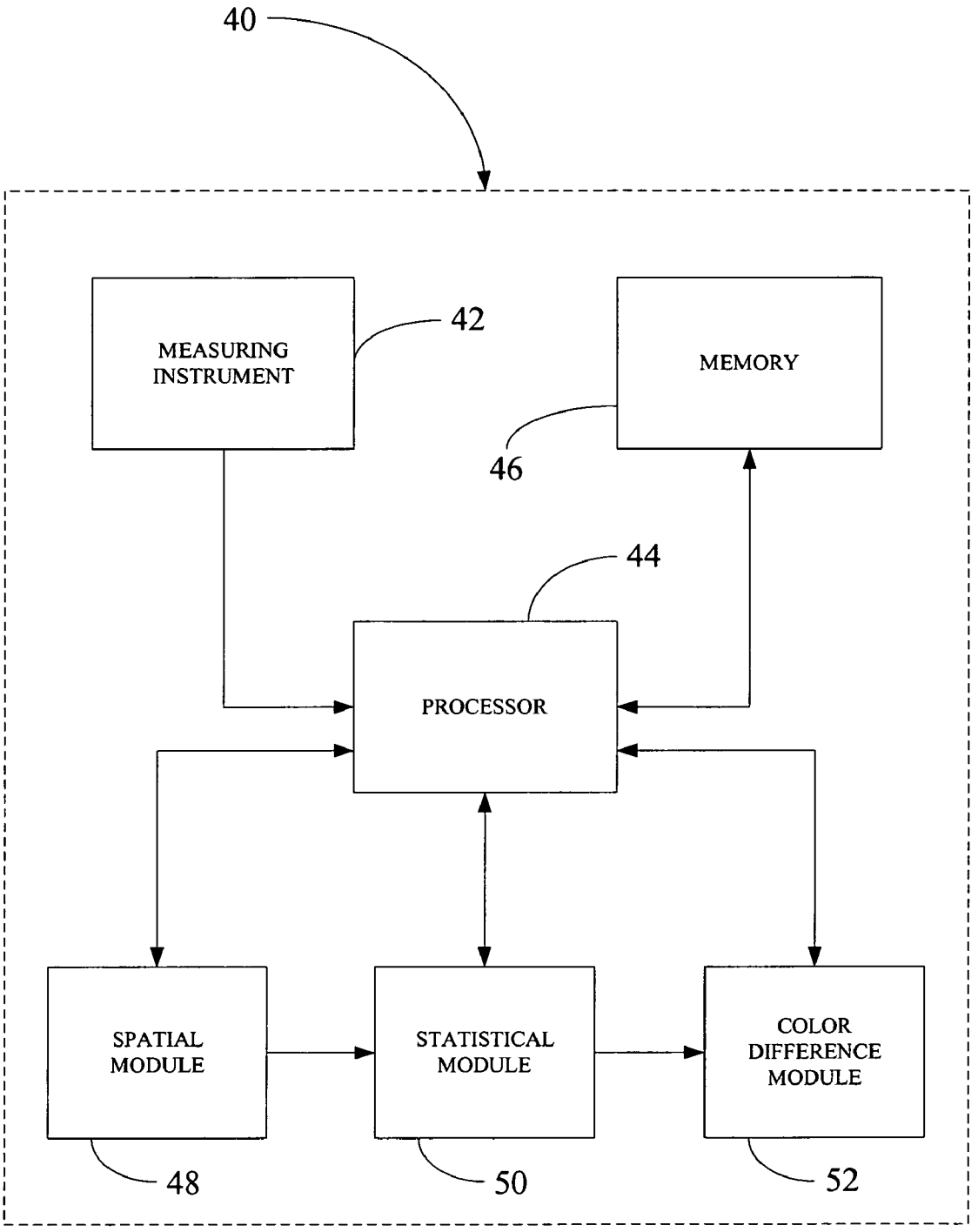

40
MEASURING INSTRUMENT
42
MEMORY
46
44
PROCESSOR
SPATIAL MODULE
STATISTICAL MODULE
COLOR DIFFERENCE MODULE
48
50
52

FIGURE 2

SYSTEMS AND METHODS FOR MEASURING A LIKE-COLOR REGION OF AN OBJECT

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the priority benefit of U.S. Provisional Patent Application No. 60/670,407, filed on Apr. 12, 2005.

BACKGROUND

[0002] This application discloses an invention that is related, generally and in various embodiments, to systems and methods for measuring a like-color region of an object.

[0003] In many production processes, it is important to know a color on an object produced by the process. It some processes, it is also important to know or control where the color exists on the object. For example, for quality control purposes, it may be important to control the color and position of a small artifact that comprises a portion of a larger object.

[0004] For some applications, it is known to utilize a handheld instrument to measure the object. Such instruments generally measure a spot on the object and have a relatively small measuring aperture. The aperture must be accurately aligned with the artifact to secure an accurate measurement. The measuring aperture must also be positioned away from any edge transition to secure an accurate measurement. For artifacts that are larger than the spot area measured by such instruments, a significant portion of the artifact may be left unmeasured.

[0005] For some applications, it is known to utilize an image scanner to measure the object. This allows for many small pixels to be measured for the entire object, including the artifact. Known machine vision algorithms are then utilized to process pixel data to identify the color and position of the artifact. However, identifying the color and position of the artifact in this manner is a relatively slow and expensive process due to the large amount of data and the significant amount of processing and storage resources required. Additionally, such systems process color in RGB, HSL, or some other color space that is not well correlated to human color vision.

SUMMARY

[0006] In one general respect, this application discloses a method for measuring a like-color region of an object. According to various embodiments, the method comprises defining a first region of a colorimetric image of the object, determining a statistical representation of the first region based on a color metric, and defining a second region of the colorimetric image such that the second region comprises at least a portion of the first region.

[0007] In another general respect, this application discloses a system for measuring a like-color region of an object. According to various embodiments, the system comprises a spatial module for defining a first region of a colorimetric image of the object, a statistical module for determining a statistical representation of the first region, and a color difference module for defining a second region of the colorimetric image such that the second region comprises at least a portion of the first region.

[0008] Aspects of the disclosed invention may be implemented by a computer system and/or by a computer program stored on a computer readable medium. The computer readable medium may comprise a disk, a device, and/or a propagated signal.

[0009] Other features and advantages will be apparent from the following description, including the drawings, and from the claims.

DESCRIPTION OF THE DRAWINGS

[0010] **FIG. 1** illustrates various embodiments of a method for measuring a like-color region of an object; and

[0011] **FIG. 2** illustrates various embodiments of a system for measuring a like-color region of an object.

DETAILED DESCRIPTION

[0012] The figures and descriptions of the disclosed invention have been simplified to illustrate elements that are relevant for a clear understanding of the disclosed invention. It should be understood that the methods, products, and systems described below may include various other processes, components, and elements in actual implementation.

[0013] **FIG. 1** illustrates various embodiments of a method **10** for measuring a like-color region of an object. The like-color region may be associated with an artifact that comprises a portion of the object, and the artifact may be of any size and shape. For example, the artifact may be an irregularly-shaped artifact.

[0014] The method starts at block **12**, where a colorimetric image of the object is obtained. The colorimetric image may be a calorimetric image of the entire object, or of just a portion of the object (e.g., a portion that includes the artifact), and may be obtained in any known manner. For example, the calorimetric image may be obtained using a hand-held measuring instrument, a scanning device, etc. According to various embodiments, spectral data associated with the object may also be obtained at block **12**.

[0015] From block **12**, the method advances to block **14**, where a first region of the colorimetric image is defined. The first region may be representative of the entire artifact, or just a portion thereof. In general, defining the first region comprises identifying the one or more pixels that comprise the first region and collectively describe the shape and location of the first region. The first region may be defined in any suitable manner. For example, according to various embodiments, a simple spatial algorithm may be utilized to define the first region. The spatial algorithm may identify a single pixel that defines the first region. The spatial algorithm may define a circle such that all of the pixels comprising the circle define the first region. The spatial algorithm may define four coordinates that describe corner pixels of a square such that all of the pixels comprising the square define the first region. The spatial algorithm may define an irregular map of pixels such as, for example, a group of pixels that looks like the state of Michigan. The first region may be considered a first crop region representative of the artifact or a portion thereof.

[0016] From block **14**, the method advances to block **16**, where a statistical representation of the first region is determined based on a color metric. To determine the statistical

representation, a color value may be determined for each pixel in the first region. The color value may be based on any known color standard. For example, the color value may be a L*a*b* value, a L*u*v* value, a L*C*H° value, an XYZ value, an xyz value, a Yxy value, a L*u'v' value, a Hunter Lab value, etc. Therefore, according to various embodiments, the color values may be determined by determining a L*a*b* value for each pixel in the first region, a L*u*v* value for each pixel in the first region, a L*C*H° value for each pixel in the first region, etc. Some statistics, such as median, will automatically reject outlier pixels from contributing to the final result. In that and other similar cases, a fraction of the pixels contained in the first region are represented in the statistical result.

[0017] Once a color value is determined for each pixel in the first region, one or more statistical representations of the first region may be determined. For example, according to various embodiments, a mean of the color values of the pixels in the first region may be determined. Similarly, a median, standard deviation, and/or a statistical moment of the color values of the pixels in the first region may be determined. In addition, other statistics such as, for example, statistics that indicate the spatial frequency of certain data may be determined. Each statistical representation may be stored in a memory. The statistical representations may serve to dramatically reduce the size of the data associated with the first region and the time required for subsequent processing. Information concerning the location of the first region in the colorimetric image may also be stored in a memory. The location may be represented in any suitable manner. For example, the location may be represented by coordinates of pixels that define the perimeter of the first region, by a coordinate of an origin in the colorimetric image, with reference to a fiducial in the colorimetric image, etc.

[0018] From block **16**, the method advances to block **18**, where a second region of the colorimetric image is defined. The second region is representative of the like-colored regions of the artifact, and is defined such that the second region comprises at least a portion of the first region. As the artifact may be an irregularly-shaped artifact, the second region may be irregularly-shaped. According to various embodiments, the second region may include just a portion of the first region, or may include the first region and additional pixels. In general, defining the second region comprises determining a difference between a target color and the color values of individual pixels. This may be done for each pixel in the first region, and for one or more pixels external to the first region. For pixels external to the first region, consideration of such pixels may be limited to pixels within a predetermined distance of the first region (a spatial threshold) or to pixels having a predefined connectedness to the first region. For example, according to various embodiments, the second region may be determined by performing a flooding operation starting at the center of the first region. For such pixels, a color value must be determined for each pixel before the difference between the color value and the target value can be determined. The target color may be, for example, the mean of the color values of the pixels of the first region, the average of the color values of the pixels of the first region, etc.

[0019] The color differences may be based on any known color difference standards. For example, according to various embodiments, the color differences may be based on CIELAB delta E units, CIE94 delta E units, CIE2000 delta E units, or CMC delta E units. The color differences may be determined in any suitable manner. For example, according to various embodiments, a color algorithm may be utilized to determine the color differences, and to determine whether particular pixels should be included in the second region based on their closeness to the target color.

[0020] The second region may be considered a second crop region representative of the artifact and is related to the color(s) described by the first crop region. The data representative of the second region may be stored in a memory. As the second region includes at least a portion of the first region, and the first region may be characterized by a statistical representation, the method **10** also serves to dramatically reduce the size of the data associated with the second region and the time required for subsequent processing.

[0021] From block **18**, the method advances to block **20**, where additional statistical processing may be utilized to further define the second region, and by association, the artifact. According to various embodiments, statistical processing may be utilized to exclude certain defects such as, for example, pinholes, nicks, scratches, specular glints, etc. from the artifact from consideration. In addition, the spectral data associated to each pixel obtained at block **12** may also be processed at block **20** to determine various spectral-based information associated with the artifact such as, for example, density, whiteness, brightness, etc. The resultant information may be stored in a memory.

[0022] According to various embodiments, the sequence of the method **10** may be altered. For example, the method may be utilized to first find regions of like-color in the colorimetric image and then determine the appropriate "crop" shape for each region.

[0023] **FIG. 2** illustrates various embodiments of a system **40** for measuring a like-color region of an object. In general, one or more elements of the system **40** may perform the method **10** as described above.

[0024] The system **40** includes a measuring instrument **42**, a processor **44**, a memory **46**, a spatial module **48**, a statistical module **50**, and a color difference module **52**. According to various embodiments, one or more of the processor **44**, the memory **46**, the spatial module **48**, the statistical module **50**, and the color difference module **52** may comprise a portion of the measuring instrument **42**. According to other embodiments, one or more of the processor **44**, the memory **46**, the spatial module **48**, the statistical module **50**, and the color difference module **52** may be separate and apart from the measuring instrument **42**. For example, as shown in FIG. **2**, the processor **44** may be in wired or wireless communication with the measuring instrument **42**, and the memory **46**, the spatial module **48**, the statistical module **50**, and the color difference module **52** may be in wired or wireless communication with the processor **44**. According to other embodiments, some system components may communicate with other system components in a different manner.

[0025] The measuring instrument **42** may be any measuring instrument suitable for taking a calorimetric image of an object. For example, the measuring instrument **42** may be a

hand-held instrument, a scanning device, etc. According to various embodiments, the measuring instrument **42** may also be configured to measure spectral data of the object. The memory **46** may be any type of memory suitable for storing data.

[**0026**] The spatial module **48** may be configured to define a first region of the colorimetric image. According to various embodiments, the first region may be representative of an artifact on the object or a portion of the artifact. Therefore, the spatial module **48** may be configured to define a first crop region in the colorimetric image representative of the artifact or a portion thereof.

[**0027**] The statistical module **50** may be configured to determine statistics representative of the first region of the calorimetric image. The statistics may include, for example, a mean of the color values of pixels in the first region, a median of the color values of pixels in the first region, a standard deviation of the color values of pixels in the first region, a statistical moment of the color values of the pixels in the first region, etc. The statistical module **50** may also be configured to determine a color value for any pixel in the colorimetric image. According to various embodiments, the statistical module **50** may also be configured to determine spectral-based information associated with the artifact such as, for example, density, whiteness, brightness, etc. based on spectral data associated with the artifact.

[**0028**] The color difference module **52** may be configured to define the second region of the colorimetric image such that the second region comprises at least a portion of the first region. According to various embodiments, the second region may be representative of the artifact of the object. Therefore, the color difference module **52** may be configured to define a second crop region in the calorimetric image representative of the artifact. The color difference module **52** may also determine a color difference between a target color and the color value of any pixel in the colorimetric image.

[**0029**] Each of the modules **48**, **50**, **52** may be implemented as software applications, computer programs, etc. utilizing any suitable computer language (e.g., C, C++, Delphi, Java, JavaScript, Perl, Visual Basic, VBScript, etc.) and may be embodied permanently or temporarily in any type of machine, component, physical or virtual equipment, storage medium, or propagated signal capable of delivering instructions to a device. The software code may be stored as a series of instructions or commands on a computer-readable medium such that when the processor **44** reads the medium, the functions described herein are performed.

[**0030**] As used herein, the term "computer-readable medium" may include, for example, magnetic and optical memory devices such as diskettes, compact discs of both read-only and writeable varieties, optical disk drives, and hard disk drives. A computer-readable medium may also include memory storage that can be physical, virtual, permanent, temporary, semi-permanent and/or semi-temporary. A computer-readable medium may further include one or more propagated signals, and such propagated signals may or may not be transmitted on one or more carrier waves.

[**0031**] Although the modules **48**, **50**, **52** are shown in **FIG. 2** as three separate modules, one skilled in the art will appreciate that the functionality of the modules **48**, **50**, **52** may be combined into a single module. Also, although the modules **48**, **50**, **52** are shown as being part of a common system **40**, the modules **48**, **50**, **52** may be installed on separate, distinct systems that are in wired or wireless communication with one another. For example, for embodiments where one or more of the modules **48**, **50**, **52** are installed on separate distinct systems, the modules may be in communication with one another via a network (not shown). Such a network may include any type of delivery system including, but not limited to, a local area network (e.g., Ethernet), a wide area network (e.g. the Internet and/or World Wide Web), a telephone network (e.g., analog, digital, wired, wireless, PSTN, ISDN, GSM, GPRS, and/or XDSL), a packet-switched network, a radio network, a television network, a cable network, a satellite network, and/or any other wired or wireless communications network configured to carry data. Such a network may also include elements, such as, for example, intermediate nodes, proxy servers, routers, switches, and adapters configured to direct and/or deliver data.

[**0032**] While several embodiments of the invention have been described, it should be apparent, however, that various modifications, alterations and adaptations to those embodiments may occur to persons skilled in the art with the attainment of some or all of the advantages of the disclosed invention. Therefore, this application is intended to cover all such modifications, alterations and adaptations without departing from the scope and spirit of the disclosed invention as defined by the appended claims.

What is claimed is:

1. A method for measuring a like-color region of an object, the method comprising:

defining a first region of a colorimetric image of the object;

determining a statistical representation of the first region based on a color metric; and

defining a second region of the colorimetric image such that the second region comprises at least a portion of the first region.

2. The method of claim 1, wherein defining the first region comprises identifying each pixel in the first region.

3. The method of claim 1, wherein determining the statistical representation of the first region comprises determining a color value for each pixel in the first region.

4. The method of claim 3, wherein determining the color value comprises determining one of the following color values:

a L*a*b* value;

a L*u*v* value;

a L*C*H° value;

a XYZ value;

a xyz value;

a Yxy value;

a L*u'v' value; and

a Hunter Lab value.

5. The method of claim 3, wherein determining the statistical representation of the first region further comprises determining a mean of the color values of the pixels in the first region.

6. The method of claim 3, wherein determining the statistical representation of the first region further comprises determining a median of the color values of the pixels in the first region.

7. The method of claim 3, wherein determining the statistical representation of the first region further comprises calculating a standard deviation of the color values of the pixels in the first region.

8. The method of claim 3, wherein determining the statistical representation of the first region further comprises determining a statistical moment of the color values of the pixels in the first region.

9. The method of claim 1, wherein defining the second region comprises determining a color difference between a target color and a color value for at least one of the following:

a pixel in the first region; and

a pixel external to the first region.

10. The method of claim 9, wherein determining the color difference comprises determining one of the following:

a CIELAB delta E;

a CIE94 delta E;

a CIE2000 delta E; and

a CMC delta E.

11. The method of claim 9, wherein defining the second region further comprises at least one of the following:

excluding a pixel in the first region from the second region based on a color difference threshold; and

including a pixel external to the first region in the second region based on the color difference threshold.

12. The method of claim 11, wherein defining the second region further comprises including the pixel external to the first region in the second region based on a spatial threshold.

13. The method of claim 1, wherein defining the second region comprises defining an irregularly shaped region.

14. The method of claim 1, further comprising determining spectral-based information associated with the second region.

15. A system for measuring a like-color region of an object, the system comprising:

a spatial module for defining a first region of a colorimetric image of the object;

a statistical module for determining a statistical representation of the first region; and

a color difference module for defining a second region of the calorimetric image such that the second region comprises at least a portion of the first region.

16. The system of claim 15, wherein the statistical module is further for determining a color value for a pixel in the calorimetric image.

17. The system of claim 15, wherein the statistical module is further for determining a color difference between a target color and a color value for a pixel in the calorimetric image.

18. The system of claim 15, wherein the statistical module is further for determining spectral-based information associated with the second region.

19. A computer program stored on a computer-readable medium, the program comprising instructions for:

defining a first region of a colorimetric image of an object;

determining a statistical representation of the first region based on a color metric; and

defining a second region of the colorimetric image such that the second region comprises at least a portion of the first region.

20. The computer program of claim 19, further comprising additional instructions for:

determining a color value for a pixel in the colorimetric image;

determining a color difference between a target color and the color value for the pixel; and

determining spectral-based information associated with the second region.

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