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(54) **SELECTION OF REGIONS WITHIN AN IMAGE**

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G06K 9/00 (2006.01)

(52) **U.S. Cl.** **382/181**; 382/100; 382/284

(58) **Field of Classification Search** 382/100, 382/181, 284
See application file for complete search history.

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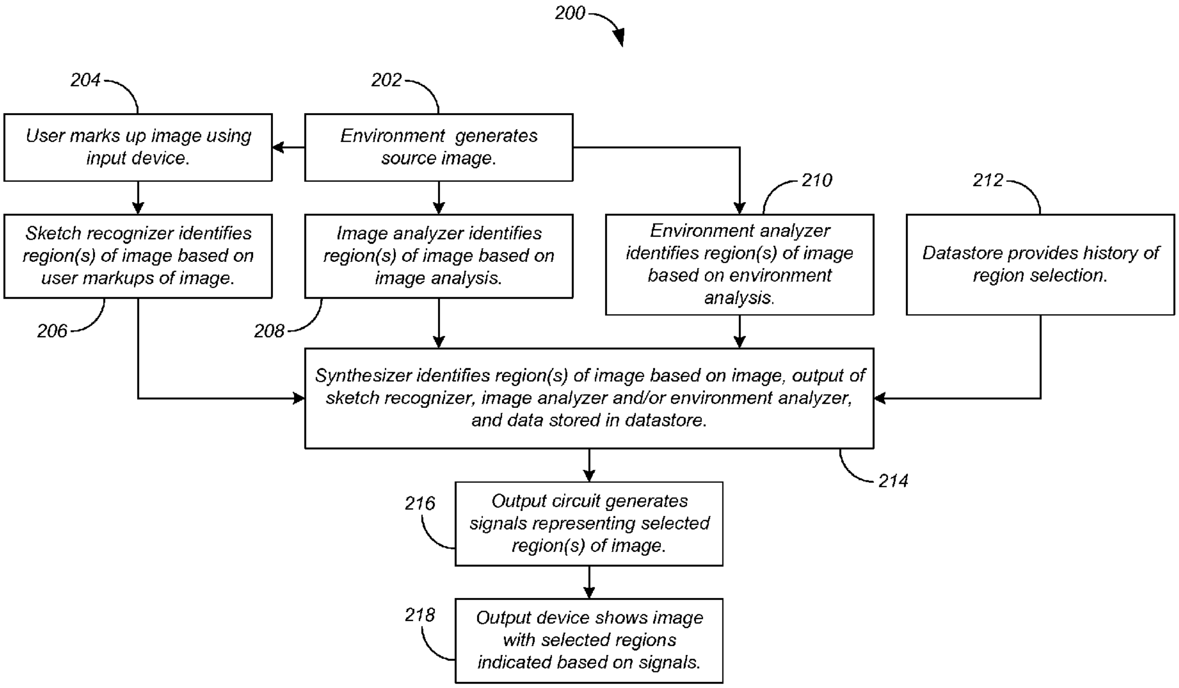
Primary Examiner—Tom Y Lu

(57) **ABSTRACT**

Apparatus having corresponding methods and computer-readable media comprise a first input circuit to receive first data describing a first region of an image, the first region identified based on user markups of the image; a second input circuit to receive second data describing at least one of a second region of the image, the second region identified by an analysis of the image, and a third region of the image, the third region identified by an analysis of an environment that produced the image; and a synthesizer to identify a fourth region of the image based on the first data and the second data.

17 Claims, 4 Drawing Sheets


200
204
User marks up image using input device.
202
Environment generates source image.
210
212
Sketch recognizer identifies region(s) of image based on user markups of image.
Image analyzer identifies region(s) of image based on image analysis.
Environment analyzer identifies region(s) of image based on environment analysis.
Datastore provides history of region selection.
206
208
Synthesizer identifies region(s) of image based on image, output of sketch recognizer, image analyzer and/or environment analyzer, and data stored in datastore.
214
216
Output circuit generates signals representing selected region(s) of image.
218
Output device shows image with selected regions indicated based on signals.

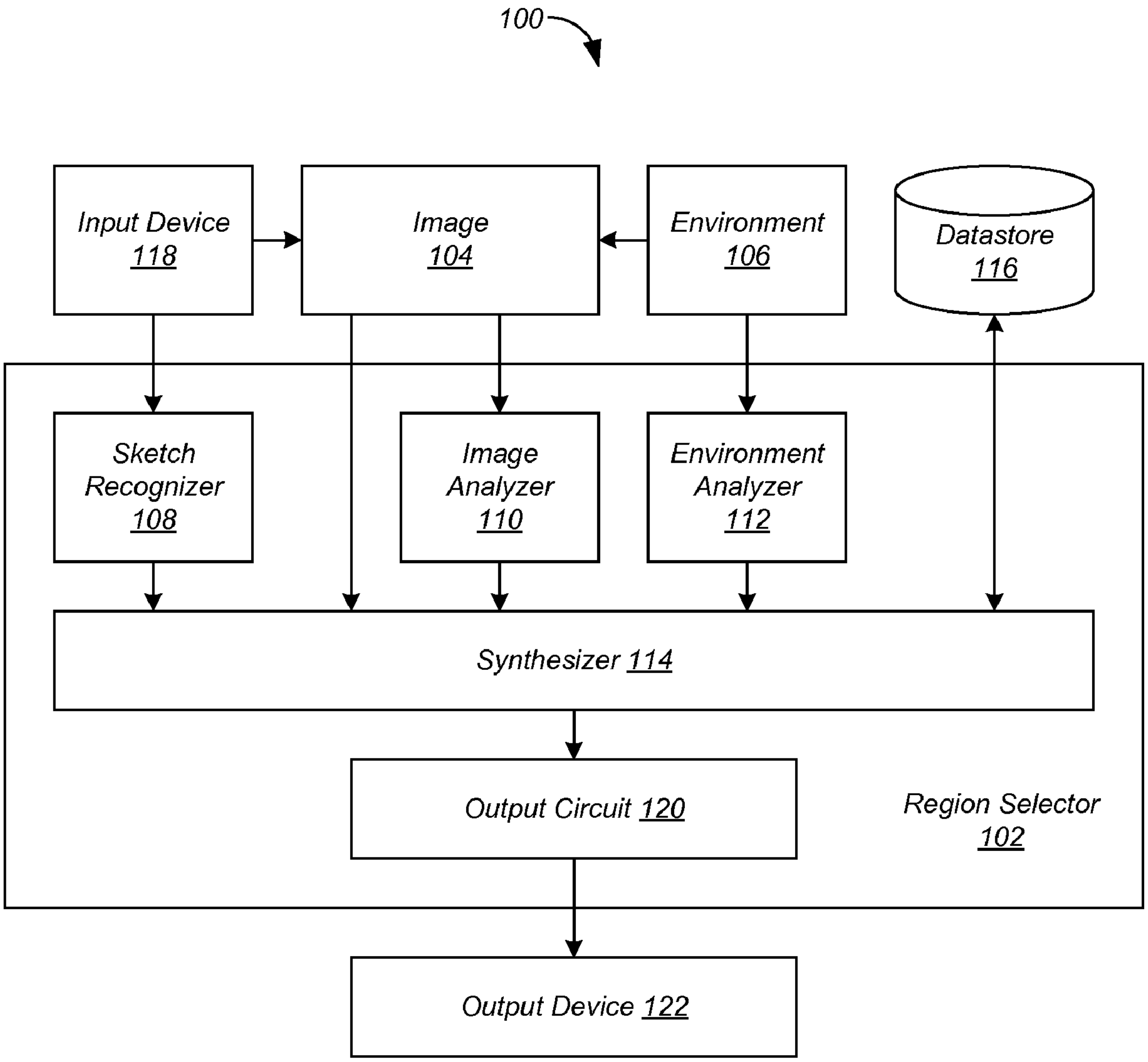
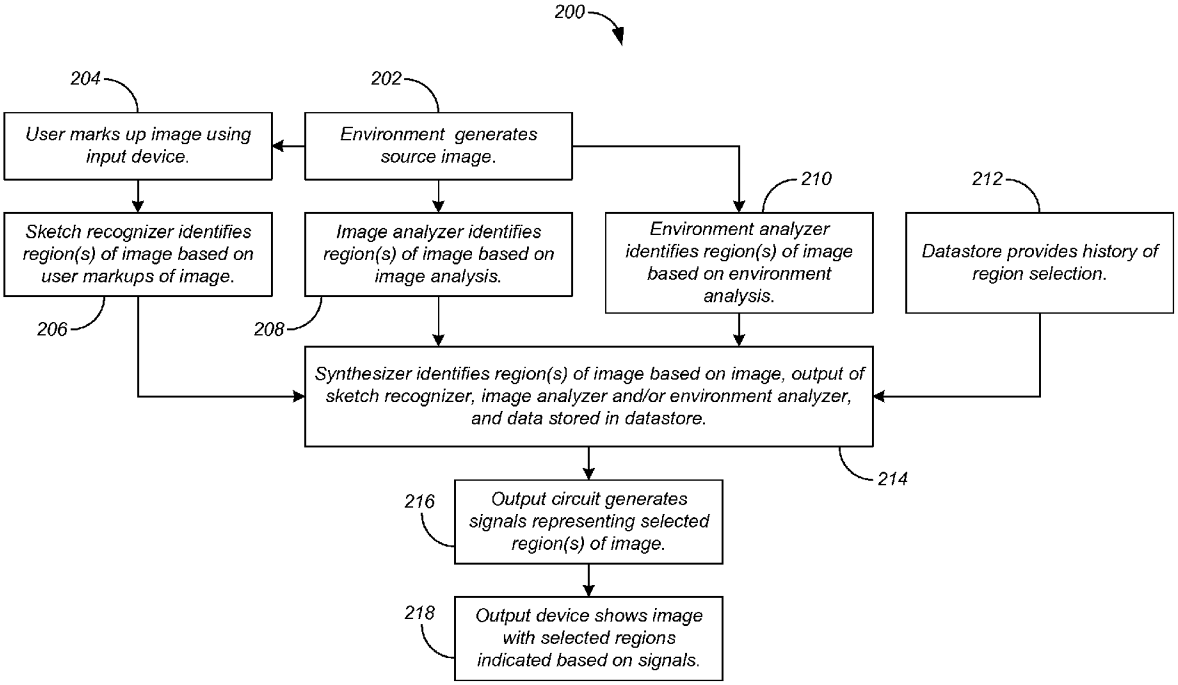

100
Input Device 118
Image 104
Environment 106
Datastore 116
Sketch Recognizer 108
Image Analyzer 110
Environment Analyzer 112
Synthesizer 114
Output Circuit 120
Region Selector 102
Output Device 122

FIG. 1


200
204
User marks up image using input device.
202
Environment generates source image.
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212
Sketch recognizer identifies region(s) of image based on user markups of image.
Image analyzer identifies region(s) of image based on image analysis.
Environment analyzer identifies region(s) of image based on environment analysis.
Datastore provides history of region selection.
206
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Synthesizer identifies region(s) of image based on image, output of sketch recognizer, image analyzer and/or environment analyzer, and data stored in datastore.
214
216
Output circuit generates signals representing selected region(s) of image.
218
Output device shows image with selected regions indicated based on signals.

FIG. 2

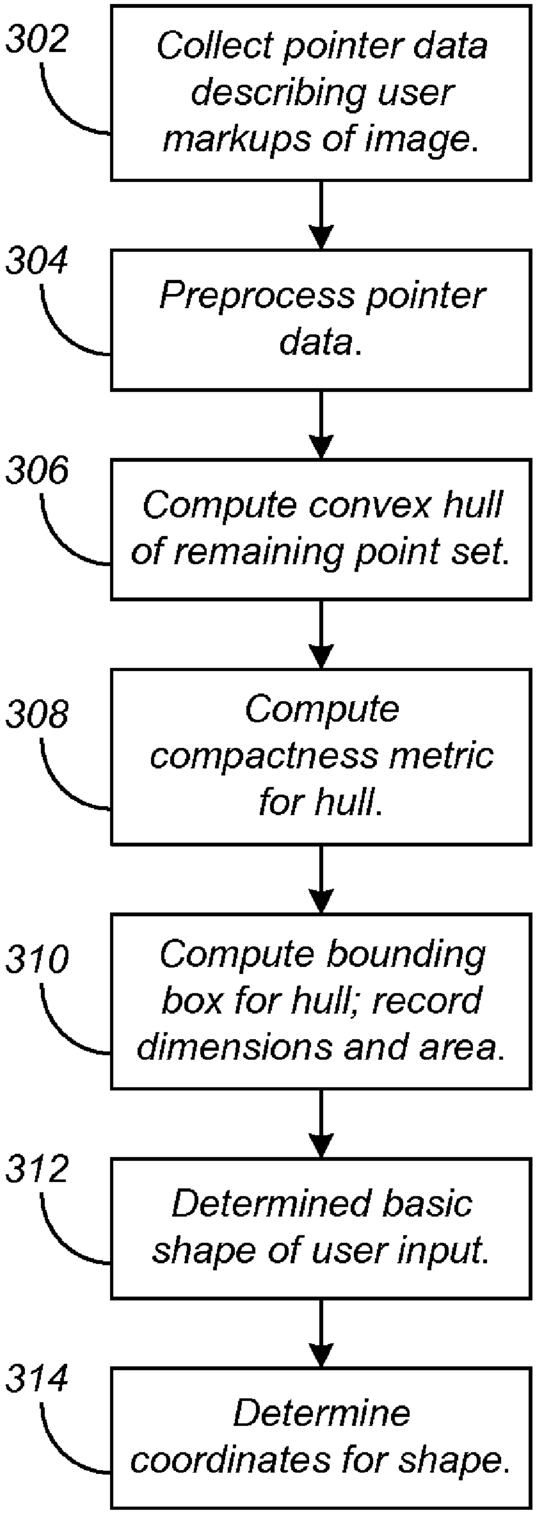
302
Collect pointer data describing user markups of image.
304
Preprocess pointer data.
306
Compute convex hull of remaining point set.
308
Compute compactness metric for hull.
310
Compute bounding box for hull; record dimensions and area.
312
Determined basic shape of user input.
314
Determine coordinates for shape.

FIG. 3

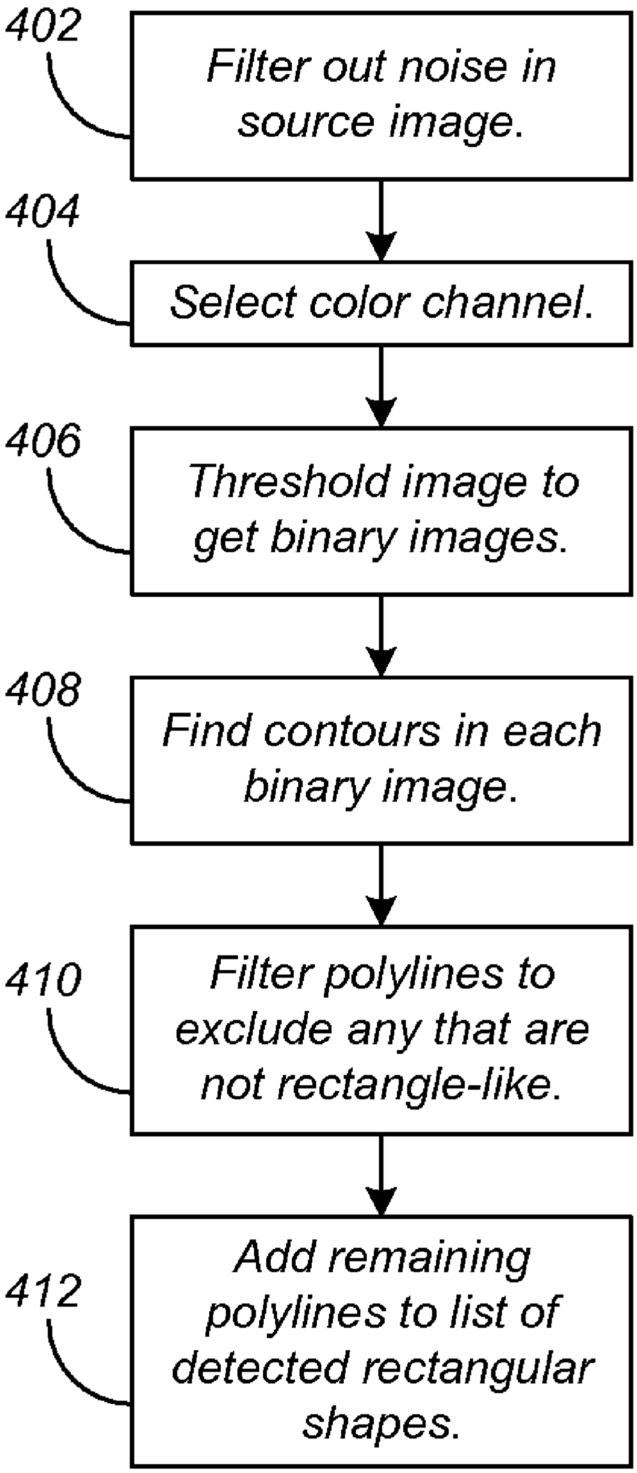
402
Filter out noise in source image.
404
Select color channel.
406
Threshold image to get binary images.
408
Find contours in each binary image.
410
Filter polylines to exclude any that are not rectangle-like.
412
Add remaining polylines to list of detected rectangular shapes.

FIG. 4

SELECTION OF REGIONS WITHIN AN IMAGE

BACKGROUND

The present invention relates generally to image processing. More particularly, the present invention relates to selection of regions within an image.

It is often the case that a person wishes to highlight a region of an image for their later recollection, to bring the region to the awareness of another person, or the like. For example, two geographically-separated engineers use a teleconferencing system to discuss components in a circuit diagram, and highlight each component as it is discussed to avoid confusion. As another example, a quality-assurance technician notices that a button in an application under test is not working properly, and highlights the button in a screen capture submitted with her problem report. As yet another example, a photographer viewing a photograph on his computer highlights an object in the background as a reminder to remove that object from the final image.

There are many possible methods for drawing visual attention to a portion of an image. For example, the image may be cropped to the significant portion. Or, a variety of drawing tools might be used to surround the significant region with the outline of a shape such as a rectangle or ellipse, or to add arrows or other markers on top of the image. Animation effects can be used to cause an important region to flash, to glow, or to have a moving border. The non-significant portions of an image might be darkened, blurred, or otherwise transformed. Yet another method is to add a callout to the image that shows a magnified view of the significant portion. Other highlighting methods are of course possible.

Many of these methods share common problems. For example, a user who does not carefully select the bounds of the highlighted region will often highlight too much or too little, requiring extra attention to correct the selection or communicate the correct selection to another person. None of these methods make use of the information contained in the image itself, which can be a photograph, a diagram, or a blank canvas. If a user wishes to highlight multiple significant regions, extra effort may be required to change the color, shape, or style of subsequent region selections.

SUMMARY

In general, in one aspect, the invention features an apparatus comprising: a first input circuit to receive first data describing a first region of an image, the first region identified based on user markups of the image; a second input circuit to receive second data describing at least one of a second region of the image, the second region identified by an analysis of the image, and a third region of the image, the third region identified by an analysis of an environment that produced the image; and a synthesizer to identify a fourth region of the image based on the first data and the second data.

Some embodiments comprise a sketch recognizer to identify the first region of the image based on the user markups of the image. Some embodiments comprise an image analyzer to perform the analysis of the image, and to identify the second region of the image based on the analysis of the image. Some embodiments comprise an environment analyzer to perform the analysis of the environment that produced the image, and to identify the third region of the image based on the analysis of the environment that produced the image. Some embodiments comprise a datastore to store third data describing a history of at least one of user markups of the image, user markups of other images, the first and second data, the first and second data for other images, the fourth region, and the fourth region for other images; and wherein the synthesizer identifies the fourth region of the image based on the first data, the second data, and the third data. Some embodiments comprise an output circuit to generate signals representing the fourth region of the image.

In general, in one aspect, the invention features an apparatus comprising: first input means for receiving first data describing a first region of an image, the first region identified based on user markups of the image; second input means for receiving second data describing at least one of a second region of the image, the second region identified by an analysis of the image, and a third region of the image, the third region identified by an analysis of an environment that produced the image; and synthesizing means for identifying a fourth region of the image based on the first data and the second data.

Some embodiments comprise sketch recognizing means for identifying the first region of the image based on the user markups of the image. Some embodiments comprise image analyzing means for performing the analysis of the image, and for identifying the second region of the image based on the analysis of the image. Some embodiments comprise environment analyzing means for performing the analysis of the environment that produced the image, and for identifying the third region of the image based on the analysis of the environment that produced the image. Some embodiments comprise means for storing third data describing a history of at least one of user markups of the image, user markups of other images, the first and second data, the first and second data for other images, the fourth region, and the fourth region for other images; and wherein the synthesizing means identifies the fourth region of the image based on the first data, the second data, and the third data. Some embodiments comprise output means for generating signals representing the fourth region of the image.

In general, in one aspect, the invention features computer-readable media embodying instructions executable by a computer to perform a method comprising: receiving first data describing a first region of an image, the first region identified based on user markups of the image; receiving second data describing at least one of a second region of the image, the second region identified by an analysis of the image, and a third region of the image, the third region identified by an analysis of an environment that produced the image; and identifying a fourth region of the image based on the first data and the second data. Some embodiments comprise identifying the first region of the image based on the user markups of the image. Some embodiments comprise performing the analysis of the image; and identifying the second region of the image based on the analysis of the image. Some embodiments comprise performing the analysis of the environment that produced the image; and identifying the third region of the image based on the analysis of the environment that produced the image. Some embodiments comprise receiving third data describing a history of at least one of user markups of the image, user markups of other images, the first and second data, the first and second data for other images, the fourth region, and the fourth region for other images; and identifying the fourth region of the image based on the first data, the second data, and the third data.

The details of one or more implementations are set forth in the accompanying drawings and the description below. Other features will be apparent from the description and drawings, and from the claims.

DESCRIPTION OF DRAWINGS

FIG. **1** shows a region selection system comprising a region selector to select regions in an image produced by an environment according to some embodiments of the present invention.

FIG. **2** shows a process for the region selection system of FIG. **1** according to some embodiments of the present invention.

FIG. **3** shows a process for a multi-stroke-aware, rule-based sketch recognition technique according to some embodiments of the present invention.

FIG. **4** shows a rectangle detection technique according to some embodiments of the present invention.

The leading digit(s) of each reference numeral used in this specification indicates the number of the drawing in which the reference numeral first appears.

DETAILED DESCRIPTION

Embodiments of the present invention enable rapid and accurate selection of regions within an image. Multiple channels of input information are used when selecting a region. The channels include outputs of a sketch recognizer and one or both of an image analyzer and an environment analyzer. The channels can also include a history of previous region selections.

FIG. **1** shows a region selection system **100** comprising a region selector **102** to select regions in an image **104** produced by an environment **106** according to some embodiments of the present invention. Region selector **102** includes a sketch recognizer **108** and one or both of an image analyzer **110** and an environment analyzer **112**. Region selector **102** also includes a synthesizer **114**. Region selection system **100** can also include a datastore **116**. Sketch recognizer **108** receives data describing user markups of image **104** from a user input device **118**. Image analyzer **110** performs an analysis of image **104**. Environment analyzer **112** performs an analysis of environment **106**.

Synthesizer **114** identifies one or more regions of image **104** based on outputs of sketch recognizer **108** and one or both of image analyzer **110** and environment analyzer **112**. Region selector **102** can also employ a history of region selections stored in datastore **116**. Region selector **102** can also include an output circuit **120** to generate signals representing the selected region(s) of image **104**, which can be displayed for example on an output device **122** such as a computer monitor and the like.

Although in the described embodiments, the elements of region selection system **100** are presented in one arrangement, other embodiments may feature other arrangements, as will be apparent to one skilled in the relevant arts based on the disclosure and teachings provided herein. For example, the elements of region selection system **100** can be implemented in hardware, software, or combinations thereof.

FIG. **2** shows a process **200** for region selection system **100** of FIG. **1** according to some embodiments of the present invention. Although in the described embodiments, the elements of process **200** are presented in one arrangement, other embodiments may feature other arrangements, as will be apparent to one skilled in the relevant arts based on the disclosure and teachings provided herein. For example, in various embodiments, some or all of the steps of process **200** can be executed in a different order, concurrently, and the like.

Environment **106** generates a source image **104** (step **202**). Environment **106** can be any environment capable of generating an image, such as a drawing application or a photograph processing application in conjunction with an underlying operating system, and the like. However, image **104** is not limited to image output from an application, but can also include images fabricated by environment **106**, images reflecting a view of environment **106**, and the like. For example, image **104** can come from an image file, from output by an image provider such as a drawing or photo application, from a capture of the current display pixel content, by generating a view of operating system windows, and the like. For example, a desktop sharing application can employ an embodiment of the present invention to allow a local or remote user to quickly identify windows, controls, buttons, applications, and the like during a live session.

A user marks up image **104** using input device **118** (step **204**). For example, the user uses a mouse to highlight a region of image **104** by circling the region with a freeform drawing tool, overlaying a geometric shape onto the region, or the like. Sketch recognizer **108** identifies one or more first regions of image **104** based on the user markups of the image (step **206**).

Sketch recognizer **108** can employ any sketch recognition technique. Many different sketch recognition techniques and algorithms exist. For example, some systems use machine learning techniques, starting with a database of known shape samples, and judging the similarity of an input against that database using a number of characteristics. Other approaches are rule-based, using hard-coded tolerances for ideal shape characteristics. Some algorithms may make use of input dimensions such as time and pressure used to draw a stroke; others rely only on the geometry of the frequently sampled pointer position.

Some embodiments of the present invention employ a multi-stroke-aware, rule-based sketch recognition technique that is easy to implement and computationally efficient. This technique is now described with reference to FIG. **3**. Further details are provided in Ajay Apte, Van Vo, Takayuki Dan Kimura, "Recognizing Multistroke Geometric Shapes: An Experimental Evaluation", Proceedings Of The 6th Annual ACM Symposium On User Interface Software And Technology, p. 121-128, December 1993, Atlanta, Ga., United States. Sketch recognizer **108** collects pointer data describing user markups of image **104** (step **302**). For example, a user starts a region selection by pressing the left button of a mouse. While the mouse button is down, all pointer movement notifications received by sketch recognizer **108** are accumulated. Releasing the mouse button (ending the drag motion) signals the end of a stroke. Multiple strokes may be used to indicate a single shape. If the user does not start a new stroke within a certain time interval, sketch recognizer **108** interprets that as the completion of the shape, and begins the process of recognizing the shape. The duration of the time interval can be constant, or can vary as a function of the stroke or shape drawn to that point. For example, the duration can be computed as a number of milliseconds equal to four times the number of point samples received as part of the active stroke, with a minimum of 500 ms and a maximum of 1500 ms.

Sketch recognizer **108** preprocesses the pointer data to improve recognition performance (step **304**). The pointer position data is condensed into a single set of points, that is, the order and distribution of points within a stroke is ignored, as are duplicate points. When a user is very rapidly drawing a closed shape with a single stroke there is often an unwanted 'tail' when the end of the stroke is accidentally carried far past the beginning of the stroke. This effect can drastically impact the shape analysis in unwanted ways, so sketch recognizer **108** checks for this case prior to forming the point set, and ignores any unwanted tail.

Sketch recognizer **108** computes the convex hull of the remaining point set (step **306**). Many techniques exist for this operation, any of which can be used. In some embodiments, sketch recognizer **108** uses the common Graham Scan method. Sketch recognizer **108** checks the hull against a few particular shapes such as point or a line segment. If there is a match, sketch recognizer **108** returns that shape. Otherwise sketch recognizer **108** computes the perimeter and area of the hull. A convex hull is a simple polygon, and its area can be computed using the Trapezoid Rule.

Sketch recognizer **108** computes a compactness metric, C, for the hull using a function of its perimeter, P, and area, A (step **308**), as shown in equations (1).

$$C = \frac{P^2}{A} \tag{1}$$

Sketch recognizer **108** also computes the minimal axis-aligned rectangle or 'bounding box' for the convex hull, and records its dimensions and area (step **310**). These values are used as inputs to a simple hierarchy of rules to decide the eventual output shape, though a more complicated system of weighted rules can be used to make this determination.

The value of the compactness C for ideal shapes is known. For example, a square with sides of length S has compactness

$$C = \frac{(4S)^2}{S^2} = \frac{16S^2}{S^2} = 16 \tag{2}$$

(constant for any value of S) and a circle with radius R has compactness

$$C = \frac{(2\pi R)^2}{\pi R^2} = \frac{4\pi^2 R^2}{\pi R^2} = 4\pi \approx 12.5664 \tag{3}$$

(constant for any value of R).

Sketch recognizer **108** can compare the hull's compactness value with these known values as an indication of the shape indicated by the pointset. For example, a well-known mathematical result is that a circle has the smallest possible value for this metric, so if C_{hull} is in the range of perhaps [4π, 4π+1] sketch recognizer **108** determines that the user was indicating a circular region. If C_{hull} is very large it means the hull is long and thin, and sketch recognizer **108** determines that the user was indicating a line. After eliminating some shapes as possibilities, others become more likely.

Sketch recognizer **108** also considers the ratio of the convex hull's area to the area of its bounding box. The convex hull and the bounding box for an axis-aligned rectangle are the same shape (the rectangle itself), so this ratio will be 1.0. If the measured ratio is near 1.0 sketch recognizer **108** returns that rectangle as the recognized shape. The area ratio for an axis-aligned ellipse will be close to 0.8, and so on. Sketch recognizer **108** can distinguish squares from other rectangles by checking if the ratio of the shape's width and height falls within a threshold. The circle vs. other ellipse distinction having already been made by that point by virtue of the compactness metric. Once sketch recognizer **108** has determined the basic shape of the user input (step **312**), sketch recognizer **108** determines the coordinates for that shape based on the input points (step **314**), also according to conventional techniques. Of course, sketch recognizer **108** can employ sketch recognition techniques other than those described above, as will be apparent to one skilled in the relevant arts based on the disclosure and teachings provided herein.

Referring again to FIG. **2**, image analyzer **110** performs an analysis of image **104**, and identifies one or more second regions of image **104** based on the analysis (step **208**). Image analyzer **110** can employ any image analysis technique. Many different image analysis techniques and algorithms exist. There are well-known techniques, for example, for identifying simple shapes such as lines, circles, and rectangles within a source image using only its pixel data, for example such as variations on the Hough Transform.

In some embodiments, image analyzer **110** employs a rectangle detection technique, as shown in FIG. **4**. The rectangle detection technique returns a list of rectangles. The described rectangle detection technique is easy to implement. In addition, rectangles are common in source images. Of course, standard image analysis techniques for detection of other shapes such as lines or circles can be used instead of, or in addition to, this rectangle-detection process.

Rectangle detection begins by filtering out noise in source image **104** (step **402**), for example by down-sampling and then up-sampling image **104** including a Gaussian blurring. An empty list is created to hold the detected rectangles. Rectangle detection is performed on each color channel (for example, red, green, and blue channels) separately (step **404**), with any rectangles discovered being added to the overall list. Each channel is treated as a grayscale image, and the image is thresholded at a number of levels (for example, 10 intervals in the 0-255 range) to get binary images (step **406**).

Image analyzer **110** finds the contours in each binary image (step **408**). Each contour is a polyline, and after being computed, is approximated with a simpler polyline, for example using the Douglas-Peucker algorithm. After simplification, image analyzer **110** filters the polylines to exclude any that are not rectangle-like (step **410**), for example, those that contain more than four vertices, or that are concave, or that contain angles radically different from 90 degrees (for example, angles that are less than 73 degrees or greater than 107 degrees). Any remaining polylines are considered rectangle-like, and are added to the list of detected rectangular shapes (step **412**).

Some rectangular shapes contain a gradient pattern, for example when the source image is a screen capture of an interactive application running in a desktop environment. To better detect these rectangles, the contour analysis can also be done once for the dilated output of the Canny edge detection algorithm on each color channel.

Referring again to FIG. **2**, environment analyzer **112** performs an analysis of the environment **106** that produced image **104**, and identifies one or more third regions of the image based on the analysis (step **210**). Knowing the environment **106** that produced source image **104** provides information as to the content of image **104**. For example, it may be known that a certain text-editing application shows only text, with no images or other diagrams. Therefore image analysis is unlikely to generate accurate shapes. On the other hand, a diagramming application is very likely to contain simple shapes such as rectangles and ellipses, so extra resources can be allocated to detecting that kind of shape, or updating the parameters of sketch recognizer **108** to improve the detection of those shapes.

As a further example, in operating systems employing graphical user interfaces, many applications are composed of multiple rectangular "windows." These windows generally include toolbars, menu bars, standard controls such as input boxes and dropdown lists, and the like. Such operating systems generally provide methods for enumerating the coordinates of these windows, which can be much more efficient than recovering that information from the pixels that make up the picture of the windows. In addition to being more computationally efficient by using stored values instead of image processing, this technique makes it irrelevant if the window is not perfectly rectangular (for example, a rounded rectangle), which can inhibit detection by image analysis alone.

As another example, conceptual regions in an image may not be connected, or can be misleadingly connected in the actual image data. For example, the source image **104** may be a snapshot of an operating system's desktop that may have disjoint or overlapping windows, causing the region corresponding to an application to no longer have a simple rectangular shape. Environment analysis can be used to highlight all physical regions corresponding to a single conceptual region when the user sketch indicates only one of the physical regions.

Datastore **116** stores a history of data such as user markups of image **104**, markups by the same user and other users of image **104** and other images, and outputs of sketch recognizer **108**, image analyzer **110**, environment analyzer **112**, and synthesizer **114** for image **104** and other images. That is, datastore **116** is used to store a history of user actions, the result of the ensuing computations, and their consequences. For example, synthesizer **114** may create a listing of regions based on outputs of sketch recognizer **108** and one or both of image analyzer **110** and environment analyzer **112**, ranking the listing by an estimate of the likelihood that the returned region matches the user's intention. If there are multiple regions that are equally probable, synthesizer **114** can offer the choice of regions to the user, recording that choice in datastore **116** to better evaluate the user's future sketches. Input from datastore **116** can also allow the synthesizer **114** to know that the user has just deleted a region much like the one synthesizer **114** is about to return, and that an alternate region or choice of regions should be returned instead. By analyzing sketches from many users, input from datastore **116** can be used to tune sketch recognizer **108** for a particular user population.

Another use for datastore **116** is to record selections made on the image **104** or related images across multiple users or sessions. For example, region selection system **100** can be used as part of a software usability testing environment. Users can be shown an image representing a software interface, and asked to indicate regions that are particularly confusing, unattractive, and the like. The aggregated responses can then be reported to user interaction or software development teams, for example using a translucent heat map-style overlay.

Datastore **116** can also be useful if region selection system **100** is providing visual feedback to the user as a shape is being drawn. If datastore **116** contains an instance of another sketch for source image **104** that started in the same area, region selection system **100** can offer that previously selected region as a possibility for the new selection.

Referring again to FIG. **2**, datastore **116** provides the history of region selection to synthesizer **114** (step **212**). Synthesizer **114** identifies one or more regions of image **104** based on the image **104**, output of sketch recognizer **108** and

one or both of image analyzer **110** and environment analyzer **112**, and data stored in datastore **116**, if used (step **214**). For example, synthesizer **114** can include input circuits to receive the outputs and data.

In some embodiments, synthesizer **114** is designed for maximum correctness. Each analysis component (that is, sketch recognizer **108** and one or both of image analyzer **110** and environment analyzer **112**) outputs an ordered list of the most likely selected regions for the input used, ranked by the 'distance' of the input to the region by some metric. This distance can be interpreted as the component's 'confidence' that the region is the one intended by the user. Synthesizer **114** receives the ordered lists, and chooses the region with the best confidence score, returns an amalgamation of the most likely regions, or the like. The technique used to resolve conflicts in the rankings can be optimized for a particular selection task or universe of source images.

In other embodiments, synthesizer **114** is designed to maximize processing speed, with analysis components consulted sequentially based on the relative cost of their computations, and with a region returned as soon as one within certain tolerances is identified. Additional regions can be computed on idle time in case the user rejects the returned region. For example, the bounding box of the user's input can be computed very quickly, and if the resulting rectangle is very close to a rectangle given by environment analyzer **112**, the more computationally expensive image analysis processing or datastore searching might be avoided.

For a simple example of region ranking, assume that the coordinates of a rectangle are designated R_{left}, R_{right}, R_{top}, and R_{bottom}. A reasonable choice for the distance function for two rectangles can be the sum of the Euclidean distance between the rectangles' top-left corners and the Euclidean distance between the rectangles' bottom-right corners:

$$D = \sqrt{(RB_{left} - RA_{left})^2 + (RB_{top} - RA_{top})^2} + \sqrt{(RB_{right} - RA_{right})^2 + (RB_{bottom} - RA_{bottom})^2} \tag{4}$$

Detected rectangles (from either image or environment analysis) can be sorted using this distance function. Candidate rectangular regions may be judged "close enough" to a user input if the value of D is below some constant or function of the user input.

Output circuit **120** generates signals representing the selected region(s) of the image (step **216**). Output device **122** shows image **104** with the selected regions indicated based on the signals provided by output circuit **120** (step **218**). For example, the selected regions can be visually distinguished through the use of grayscale conversion and a translucent black overlay, can be outlined with a very thin colored line, and the like. This makes the selected regions more visible when they intersect a black region of the source image **104**, as pure black regions are unaffected by both grayscale conversion and composition with a translucent black overlay. Of course, there are many possible visual representations of selected regions, and that representation may be chosen based on knowledge of the context or the universe of source image inputs. Furthermore, the output is not limited to a visual representation on a computer screen, but can also include storage or transmission of the significant region coordinates, and the like.

Process **200** can be employed iteratively to refine the output. For example, synthesizer **114** can output a set of likely regions based on the initial input (for example, the top three possibilities), thereby allowing the user to select the best region. As another example, sketch recognizer **108** can update synthesizer **114** with a "sketch guess" before sketch recognition is fully completed. Synthesizer **114** can produce intermediate results, which can be displayed in a different manner than final results. Say sketch recognizer **108** has found an elliptical region based on a careless sketch input, and the intermediate results from synthesizer **114** show the ellipse rather than the rectangle the user is expecting. This feedback to the user about the current sketch recognition result allows the user to more carefully continue drawing and sharpening the corners of the region during the sketch so that sketch recognition finds the desired rectangular region, and synthesizer **114** produces the final results required.

The invention can be implemented in digital electronic circuitry, or in computer hardware, firmware, software, or in combinations of them. Apparatus of the invention can be implemented in a computer program product tangibly embodied in a machine-readable storage device for execution by a programmable processor; and method steps of the invention can be performed by a programmable processor executing a program of instructions to perform functions of the invention by operating on input data and generating output. The invention can be implemented advantageously in one or more computer programs that are executable on a programmable system including at least one programmable processor coupled to receive data and instructions from, and to transmit data and instructions to, a data storage system, at least one input device, and at least one output device. Each computer program can be implemented in a high-level procedural or object-oriented programming language, or in assembly or machine language if desired; and in any case, the language can be a compiled or interpreted language. Suitable processors include, by way of example, both general and special purpose microprocessors. Generally, a processor will receive instructions and data from a read-only memory and/or a random access memory. Generally, a computer will include one or more mass storage devices for storing data files; such devices include magnetic disks, such as internal hard disks and removable disks; magneto-optical disks; and optical disks. Storage devices suitable for tangibly embodying computer program instructions and data include all forms of nonvolatile memory, including by way of example semiconductor memory devices, such as EPROM, EEPROM, and flash memory devices; magnetic disks such as internal hard disks and removable disks; magneto-optical disks; and CD-ROM disks. Any of the foregoing can be supplemented by, or incorporated in, ASICs (application-specific integrated circuits).

A number of implementations of the invention have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the invention. Accordingly, other implementations are within the scope of the following claims.

What is claimed is:

1. An apparatus comprising:

a first input circuit to receive first data describing a first region of an image, the first region identified based on user markups of the image;

a second input circuit to receive second data describing at least one of

a second region of the image, the second region identified by an analysis of the image, and

a third region of the image, the third region identified by an analysis of an environment that produced the image; and

a synthesizer to identify a fourth region of the image based on the first data and the second data.

2. The apparatus of claim **1**, further comprising:

a sketch recognizer to identify the first region of the image based on the user markups of the image.

3. The apparatus of claim **1**, further comprising:

an image analyzer to perform the analysis of the image, and to identify the second region of the image based on the analysis of the image.

4. The apparatus of claim **1**, further comprising:

an environment analyzer to perform the analysis of the environment that produced the image, and to identify the third region of the image based on the analysis of the environment that produced the image.

5. The apparatus of claim **1**, further comprising:

a datastore to store third data describing a history of at least one of

user markups of the image,

user markups of other images,

the first and second data,

the first and second data for other images,

the fourth region, and

the fourth region for other images; and

wherein the synthesizer identifies the fourth region of the image based on the first data, the second data, and the third data.

6. The apparatus of claim **1**, further comprising:

an output circuit to generate signals representing the fourth region of the image.

7. An apparatus comprising:

first input means for receiving first data describing a first region of an image, the first region identified based on user markups of the image;

second input means for receiving second data describing at least one of

a second region of the image, the second region identified by an analysis of the image, and

a third region of the image, the third region identified by an analysis of an environment that produced the image; and

synthesizing means for identifying a fourth region of the image based on the first data and the second data.

8. The apparatus of claim **7**, further comprising:

sketch recognizing means for identifying the first region of the image based on the user markups of the image.

9. The apparatus of claim **7**, further comprising:

image analyzing means for performing the analysis of the image, and for identifying the second region of the image based on the analysis of the image.

10. The apparatus of claim **7**, further comprising:

environment analyzing means for performing the analysis of the environment that produced the image, and for identifying the third region of the image based on the analysis of the environment that produced the image.

11. The apparatus of claim **7**, further comprising:

means for storing third data describing a history of at least one of

user markups of the image,

user markups of other images,

the first and second data,

the first and second data for other images,

the fourth region, and

the fourth region for other images; and

wherein the synthesizing means identifies the fourth region of the image based on the first data, the second data, and the third data.

12. The apparatus of claim **7**, further comprising:

output means for generating signals representing the fourth region of the image.

13. Non-transitory computer-readable media embodying instructions executable by a computer to perform a method comprising:

receiving first data describing a first region of an image, the first region identified based on user markups of the image;

receiving second data describing at least one of

a second region of the image, the second region identified by an analysis of the image, and

a third region of the image, the third region identified by an analysis of an environment that produced the image; and

identifying a fourth region of the image based on the first data and the second data.

14. The computer-readable media of claim **13**, wherein the method further comprises:

identifying the first region of the image based on the user markups of the image.

15. The computer-readable media of claim **13**, wherein the method further comprises:

performing the analysis of the image; and

identifying the second region of the image based on the analysis of the image.

16. The computer-readable media of claim **13**, wherein the method further comprises:

performing the analysis of the environment that produced the image; and

identifying the third region of the image based on the analysis of the environment that produced the image.

17. The computer-readable media of claim **13**, wherein the method further comprises:

receiving third data describing a history of at least one of

user markups of the image,

user markups of other images,

the first and second data,

the first and second data for other images,

the fourth region, and

the fourth region for other images; and

identifying the fourth region of the image based on the first data, the second data, and the third data.

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