A METHOD AND SYSTEM FOR LOCALIZING HUMAN IRIS AND DETERMINING HUMAN GAZE DIRECTION FOR STATISTICAL APPLICATIONS

Field of the Invention

[0001] The present invention generally relates to determining gaze direction of individuals. In particular, the invention relates to a method and system for localizing human iris and determining human gaze direction of individuals from a digital image.

Background of the Invention

[0002] Image analysis of digital images to determine directional gaze of individuals have been a recent development in the field of image processing.

[0003] Some of the applications may be used during an exhibition, a seminar or in a shopping complex. The intention is to determine whether a particular exhibit or advertisement is attractive and attention grabbing. The determining of directional gaze can further be used to assess the response of an audience to a speaker or lecturer or even to a salesman presenting a sales pitch.

[0004] Other applications may include the rapid gathering of statistical information on human directional head count in real time. For example, in big scale exhibitions, directional gaze determination may be used to determine how many visitors have visited a particular exhibit, the gaze retention period for each exhibit, and the specific flow pattern of visitors. Statistics on the attractiveness of each exhibit may further be gathered using directional gaze determination. This is achieved through the tracking of human head, iris, and the viewing directions in real time.

[0005] Traditionally, such tracking of head directions and gaze directions were determined manually. Researchers or data collectors would place a video camera behind a subject, possibly an exhibit and record down the exhibit visitors at the exhibition as they pass by, stop or visit the particular exhibit. The researcher and data collectors would then replay the video tape and count or take notes of the reactions of visitors on the tape. The researchers and data collectors also try to attempt to ascertain from their experience whether the visitors directional gaze were directed at the exhibit or not.

[0006] Such practices are tedious and easily subject to human error. Present techniques using digital image capture followed by software analysis have proven to be much more effective.

[0007] However, present software techniques are computationally expensive and require high processing capabilities and time to calculate and obtain the necessary results. Examples of computationally intensive software algorithms include normalized cross-correlation algorithm, and Circular Hough Transform algorithm for the localization of iris.

[0008] It can thus be seen that there exists a need for a simple and robust way for a method and system for localizing human iris and determining human gaze direction of individuals from a digital image that can overcome the disadvantages of the existing prior art.

Summary of the Invention

[0009] The present invention seeks to provide a method and system for localizing human iris and determining human gaze direction of individual in a digital image.

[0010] Accordingly, in one aspect, the present invention provides, a method for detecting and determining gaze direction of individuals from a digital image comprising the steps: detecting and locating possible image of human head from the digital image; detecting and locating image of eyebrows and image of eye on detected image of human head; determining boundary chain code of external boundary of sclera of the image of eye; comparing the boundary chain code with eye boundary chain code database; detecting iris of the image of eye; and determining eye gaze direction of the image of eye.

[0011] In another aspect, the present invention provides, a method for detecting and determining gaze direction of individuals from a digital image comprising the steps: detecting and locating possible image of human head from the digital image; detecting and locating image of eyebrows and image of eye on detected image of human head; determining boundary chain code of external boundary of sclera of the image of eye; calculating first difference of the boundary chain code to produce a first difference boundary chain code; comparing the first difference boundary chain code with eye boundary chain code database; detecting iris of the image of eye; and determining eye gaze direction of the image of eye.

[0012] In yet another aspect, the present invention provides, a method for detecting and determining gaze direction of individuals from a digital image comprising the steps: detecting and locating possible image of human head from the digital image; detecting and locating image of eyebrows and image of eye on detected image of human head; determining boundary chain code of external boundary of sclera of the image of eye; calculating first difference of the boundary chain code to produce a first difference boundary chain code; calculating normalized first difference boundary chain code from the first difference boundary chain code; comparing the normalized first difference boundary chain code with eye boundary

chain code database; detecting iris of the image of eye; and determining eye gaze direction of the image of eye.

[0013] In a further aspect, the present invention provides, an image processing system for determining gaze direction of individuals from a digital image comprising: a head detector for detecting a possible image of a human head from the digital image; a head boundary processor for determining a boundary chain code of the possible image of the human head; an eye detector for detecting image of eye of detected image of the human head by performing line cutting techniques producing eye line cutting data; an eye boundary processor for determining a boundary chain code of external boundary of sclera of the detected image of eye; an eye boundary chain code database for storing a plurality of eye boundary chain codes; an eye boundary chain code comparator for comparing the boundary chain code of sclera with the plurality of eye boundary chain codes; an iris detector for detecting image of iris of the detected image of eye by performing line cutting techniques producing iris line cutting data; an iris direction database for storing a plurality of iris direction data; and an iris direction determinator for determining the gaze direction of the image of iris by comparing results from comparision of the iris line cutting data from the iris detector and the iris line cutting database.

[0014] In yet a further aspect, the present invention provides, an image processing system for determining gaze direction of individuals from a digital image comprising: a head detector for detecting a possible image of a human head from the digital image; a head boundary processor for determining a boundary chain code of the possible image of the human head; an eye detector for detecting image of eye of detected image of the human head by performing line cutting techniques producing eye line cutting data; an eye boundary processor for determining a boundary chain code of external boundary of sclera of the detected image of eye; a first difference processor for calculating a first difference boundary chain code from the boundary

chain code of external boundary of sclera of the detected image of eye; an eye boundary chain code database for storing a plurality of eye boundary chain codes; an eye boundary chain code comparator for comparing the first difference boundary chain code with the plurality of eye boundary chain codes; an iris detector for detecting image of iris of the detected image of eye by performing line cutting techniques producing iris line cutting data; an iris direction database for storing a plurality of iris direction data; and an iris direction determinator for determining the gaze direction of the image of iris by comparing results from comparision of the iris line cutting data from the iris detector and the iris line cutting database.

[0015] In yet another aspect, the present invention provides, an image processing system for determining gaze direction of individuals from a digital image comprising: a head detector for detecting a possible image of a human head from the digital image; a head boundary processor for determining a boundary chain code of the possible image of the human head; an eye detector for detecting image of eye of detected image of the human head by performing line cutting techniques producing eye line cutting data; an eye boundary processor for determining a boundary chain code of external boundary of sclera of the detected image of eye; a first difference processor for calculating a first difference boundary chain code from the boundary chain code of external boundary of sclera of the detected image of eye; a normalized first difference processor for calculating a normalized first difference boundary chain code from the first difference boundary chain code; an eye boundary chain code database for storing a plurality of eye boundary chain codes; an eye boundary chain code comparator for comparing the normalized first difference boundary chain code with the plurality of eye boundary chain codes; an iris detector for detecting image of iris of the detected image of eye by performing line cutting techniques producing iris line cutting data; an iris direction database for storing a plurality of iris direction data; and an iris direction determinator for determining the gaze

direction of the image of iris by comparing results from comparision of the iris line cutting data from the iris detector and the iris line cutting database.

Brief Description of the Drawings

[0016] A preferred embodiment of the present invention will now be more fully described, with reference to the drawings of which:

[0017] FIG.1 illustrates a elements of a system for determining gaze direction of individuals from a digital image;

[0018] FIG.2 illustrates a block diagram of an image processing system for determining gaze direction of individuals from a digital image in accordance with the present invention;

[0019] FIG.3 illustrates flow chart for a method for the system in FIG.2;

[0020] FIG. 4 illustrates the step of detecting and locating image of human head of FIG. 3;

[0021] FIG. 5 illustrates the step of confirming detected image of human head of FIG. 3;

[0022] FIG. 6 illustrates the step of detecting and locating eye brows and eyes on detected image of human head of FIG. 3;

[0023] FIG. 7 illustrates the step of detecting iris of eye of FIG. 3;

[0024] FIG. 8A and FIG. 8B illustrates examples of FIG. 4 and FIG. 5; and

[0025] FIG. 9 illustrates an examples of FIG. 7.

Detailed description of the Drawings

[0026] A method and system for determining gaze direction with a preferred embodiment is described. In the following description, details are provided to describe the preferred and the alternate embodiment. It shall be apparent to one skilled in the art, however that the invention may be practiced without such details. Some of the details, examples of which are boundary chain code and line cutting techniques may not be described at length so as not to obscure the invention.

[0027] A gaze direction determining system in accordance with the present invention uses a boundary tracing process to determine external boundary features of an image of a human head and the external boundary features of images of the eyes. Referring to FIG. 8B and FIG. 9, a boundary chain code 50a,b derived from the image of a human head 19a,b and image of an eye 21 are used to determine a representation of the outline of the image of the human head 19a,b and the outline of the image of the sclera 22 of the eye 21.

[0028] Selective line-cutting processes are performed to further locate and identify internal features of the image of the human head 19a,b and the image of the eye 21. The boundary chain code 50a,b derived and the results from the line-cutting processes are compared with existing databases for possible matches and determination of gaze direction of the image of the human head 19a,b. The results from such a gaze direction determining system may easily be incorporated into a statistical gathering system for real time tracking purposes.

[0029] Such a system employs external boundary tracing using chain codes and line cutting processes which are readily performed on a computer, the present invention can advantageously be performed by an ordinary desktop personal computer.

[0030] Referring to FIG. 1, a typical system 100 in accordance with the present invention comprises a vision system 105 and an image processing system 110. The vision system 105 includes camera 115, which provides a video signal representing the image of whatever the camera 115 is directed at. The video signal is provided to an image frame grabber 120 which, when triggered, captures a particular frame of the video signal, stores the pixel data of the captured image, and makes the stored pixel data available to the image processing system 110. The camera 115 comprises a progressive scan camera, model number CV- M10BX camera manufactured by JAI Corporation of Denmark. The image frame grabber 120 comprises an IC-ASYNC gray scale frame grabber card manufactured by Coreco Imaging Inc. of Canada.

[0031] The image processing system 110 comprises a desktop computer running software programs that provide the desired functionality. The desktop computer can comprise a Pentium IV microprocessor powered machine, where Intel Inc. of the United States of America manufactures the Pentium IV microprocessor. Typically, the desktop computer includes a controller 130 that is coupled to access and control the operation of the image frame grabber 120. In addition, the controller 130 is coupled to random access memory 135, read-only-memory 140, one or more hard disk drives 145, and user interface 150. The operation of the desktop computer is known to one skilled in the art, and will not be further elaborated here, except where such details assist in the description of the present invention.

[0032] Referring to FIG. 2, an image processing system 200 in accordance with the present invention comprises a head detector 210 which receives an input of a digitally captured colour image 205. The head detector 210 is adapted for detecting

images of human head 19a, b that may be found in the digitally captured colour image 205. The head detector 210 is coupled to a head boundary processor 215 which performs a boundary tracing process on detected images of human heads 19a, b and provides a boundary chain code 50a, b for the detected image of human heads 19a, b. The head boundary processor 215 is further coupled to a head boundary chain code database 217 where data from the head boundary processor 215 may be compared.

[0033] The head boundary chain code database 217 stores a plurality of boundary chain codes 50a, b and the plurality of boundary chain codes 50a, b are for comparing with the boundary chain code 50a, b from the head boundary processor 215. The plurality of boundary chain codes 50a, b stored in the database 217 comprises a plurality of possible chain codes from various possible images of various head shapes.

[0034] Referring to FIG. 8B, an example of a boundary chain code 50a for the image of the human head 19b is GHBCDEF. Each letter in the boundary chain code 50a represents a section of a boundary representation of the image of the human head 19b. Chain code representation 45 allows the representation of boundaries over eight directions from D counter clockwise to C, where each letter represents a boundary representation in a particular direction. Another example can be seen in FIG. 9, where an image of an eye 21 is shown where the boundary chain code 50b of the sclera 22 of the eye 21 is HCEF.

[0035] The head boundary processor 215 of the image processing system 200 is further coupled to an eyes detector 220 which is adapted to detect images of eyebrows and eyes 21 of detected images of human heads 19a,b and to determine whether the eyes are open or shut.

[0036] The eye detector 220 performs a line cutting process on the detected images of human heads to determine the absence or presence, and if present, whether open or shut conditions of the images of the eyes 21. The eye detector does this by comparing line cutting data produced from the eye detector 220 with predetermined line cutting instructions stored in the eye detector 220.

[0037] The line cutting process involves a line of pixels on the images being scanned through pixel by pixel. If any of the pixels in the line encounter a drastic change in contrast or in color, a "line cut" is considered to have occurred. An example would be a line cutting of a vertical line down an eyebrow where the line meets the edge of the image of an eyebrow.

[0038] The eyes boundary processor 225 performs a boundary tracing process on the images of the sclera 22 of the detected image of the eye 21 and provides a boundary chain code 50a, b for each of the detected images of the sclera.

[0039] The eye boundary processor 225 is also coupled to a first difference processor 230 which is adapted to take an input of a boundary chain code 50a, b and performing a first difference calculation produces a first difference boundary chain code. The first difference boundary chain code caters to the different possible orientations of the image of the scelra 22 of the eye 21. The first difference calculation allows the various possible orientations and rotations of the eye 21 to be compared easily with a standard orientation.

[0040] The first difference processor takes an input of a boundary chain code and reduces it to the most basic form of representation that may be represented by the chain code representation. Referring to FIG. 8b, the eight letters D to C are assigned a number where A is 1, B is 2, C is 3, D is 4, E is 5, F is 6, G is 7 and running counterclockwise until H is assigned to 8.

[0041] Using an example of a boundary chain code of ACF, starting with the last letter F, obtain the difference between F and A. F is three letters from A, thus the difference is 3. Difference between A and C is 2, while the difference between C an F is 3. The numbers 3, 2 and 3 are then matched with the letters assigned to them, thereby producing the first difference boundary chain code CBC. Referring to FIG. 9, the boundary chain code 50b of the image of the sclera 22 of the eye 21 is HCEF. Calculating the difference in letters starting from the last letter to each of the subsequent letters, the difference is matched to the assigned letters of the boundary chain code representation 45 and the corresponding first difference boundary chain code is BCBA.

[0042] The first difference processor 230 outputs the first difference boundary chain code of the image of the sclera of the eye to an eye boundary chain code comparator 240. The eye boundary chain code comparator 240 then performs a comparison with an eye boundary chain code database 245 to find a match or a closest match.

[0043] The first difference processor 230 may further comprise a normalized first difference processor 235. The normalized first difference processor 235 is adapted to perform calculations on the first difference boundary chain code to obtain a normalized first difference boundary chain code. The normalized first boundary chain code allows the eye boundary chain code comparator 240 to more easily find a match as the eye boundary chain code database 245 would be smaller.

[0044] The first difference boundary chain code can further be normalized to the normalized first difference boundary chain code. The first difference chain code from the earlier example is CBC or corresponding to the numbers assigned is 323. The smallest integer in the corresponding numbers is 2. The entire set of numbers

preceding 2 is then rotated to the rear of the set of corresponding numbers to obtain the normalized first difference boundary chain code which is 233 or BCC.

[0045] For example a boundary chain code of BAABAA, which corresponds to 211211, the normalized first difference boundary chain code is then represented by 112112. In this case, the smallest integer is 1, which occurs four times, and therefore resulting in 4 possible choices for rotating numbers to the rear. The selection which results in the lowest value is considered the normalized first difference boundary chain code. In yet another example of a first difference chain code represented by 217211, the lowest integer 1 occurs three times. However, rotating the numbers preceding the second last integer will result in 112172 which has the lowest value and is thus the normalized first difference boundary chain code.

[0046] The normalized first difference boundary chain code requires more time and processing power to be calculated then the first difference boundary chain code. However, the eye boundary chain code database 245 for the normalized first difference boundary chain code can be much smaller and thus utilizes less memory space.

[0047] The eye boundary chain code database 245 stores a plurality of chain codes and the plurality of chain codes are for comparing with the boundary chain code from the first difference processor 230. The plurality of chain codes stored in the eye boundary chain code database 245 comprises a plurality of possible chain codes from various possible images of various sclera of an eye..

[0048] The eye boundary chain code comparator 240 is coupled to an iris detector 250 which is adapted to use line cutting processes to further determine the location of the image of the iris relative to the image of the eye. The iris detector 250 is

coupled to an iris line cutting database 255 which compares the line cutting results from the iris detector 250 to that of data in the iris line cutting database 255 to confirm the position of the iris.

[0049] The iris detector 250 is also coupled to an iris direction determinator 260. The iris direction determinator 260 takes the line cutting results from the iris detector 250 and compares them with data from an iris direction database 265 to determine the gaze direction of the image of the iris. This also results in the determination of the gaze of the image of the humanoid head of the captured digital image.

[0050] Referring to FIG. 3 and FIG. 8A, the method 300 in accordance with the present invention starts with the step of receiving 310 a captured color digital image 205. The captured color digital image 205 then undergoes the detecting and locating 315 of possible images of human heads by the head detector 210.

[0051] The method 300 proceeds to the next step where the positions of the possible images of human heads are then confirmed 320 by the head boundary processor 215 to be detected images of human heads.

[0052] Next, the images of the eyebrows and eyes on the detected images of human heads are detected and located 325 by the eyes detector 220.

[0053] The method 300 then continues to the next step where the boundary chain code of the external boundary of the sclera of the eye is determined 335 by the eye boundary processor 225. A first difference chain code is then calculated 340 using the first difference processor 230. The sclera of the eye is the "white" portion of the eyeball then forms the bulk of the eye. The first difference boundary chain code of the sclera is then compared 345 with data in the eye boundary chain code

database 245. The first difference boundary chain code allows less data to be stored in the eye boundary chain code database 225. If the first difference had not been calculated, the data in the eye boundary chain code database 225 would have had to cater to all possible variations and orientations of the image of the eye.

[0054] Further calculating a normalized first difference boundary chain code by the normalized first difference processor 235 coupled to the first difference processor 230 can further reduce the data that needs to be stored in the eye boundary chain code database. Consequently, it is the normalized first difference boundary chain code that is compared with the data in the eye boundary chain code database 225.

[0055] Following which, the images of the iris on the detected image of the eye is detected 350 by the iris detector 250 using line cutting processes. The results from the iris detector 250 are compared with the iris line cutting database 255 and together with the iris direction determinator 260 and the iris direction database 265; the step of determining the eye gaze direction 355 is then performed.

[0056] Referring to FIG. 4 and FIG. 8A, the step of detecting 315 and locating images of human heads on the digitally captured color image 205 starts with the step of dividing 410 the digitally captured color image 205 into a predetermined number of sectors 35. An example is shown in FIG. 8A where the digitally captured colour image 205 is divided into sixteen sectors 35. Next, the color histogram of each sector 35 is computed 415. Then the calculated color histograms of each sector are compared 420 with predetermined skin tone colors. Sectors 35 matching 425 skin tone colors are considered to contain a possible image of a head and are thus marked 440 as a possible human head and the location is stored 445 for further processing later in the head boundary processor 215.

[0057] If the color histograms of the sectors 35 do not match 425 the predetermined skin tone colors, it could be that none of the images of faces or heads are large enough to occupy a single sector substantially. Or that the images of the faces and heads are too small to be detected. The sectors are then further divided 410 into a predetermined number of subsectors 37 and the color histogram of the subsectors 37 individually computed 415 and compared 420 with the predetermined skin tone colors again.

[0058] If any of the sectors 35 or subsectors 37 in the digitally captured color image 205 match 425 the predetermined skin tones colors, the sector 35 or subsector 37 is marked 440 as a possible human head. The location of the possible image of a human head is then stored 445.

[0059] If the color histograms of all the subsectors still do not match the predetermined skin tone colors, the method ends and no human head is detected 435.

[0060] Alternatively, the method may further proceed and divide 410 each of the subsectors 37 into a predetermined number of even smaller sectors and the method of detecting 315 the image of the human head repeated, but with the even smaller sectors. It can be envisaged that the sectors 35 may be divided again and again into smaller and smaller sectors for detecting 315 of the image of the human head.

[0061] Referring to FIG. 5, the step of confirming 320 the possible image of the human head starts with segmenting 510 the marked 440 possible image of the human head. Segmentation of a color image converts the digitally captured color image 205 into a binary black and white image. This simplifies the other image processing steps of obtaining the boundary chain code and the line cutting.

[0062] Next, the determining 515 of the chain code of the external boundary of the possible image of the human head using the human head boundary processor 215. Following that, the boundary chain code obtained from the human head boundary processor 215 is compared 520 with the head boundary chain code database 217. If the boundary chain code from the head boundary processor 215 matches at least one in the head boundary chain code database 217, the possible image of the human head is confirmed 530 to be a detected image of a human head.

[0063] Referring to FIG. 6, the step of detecting and locating 325 of the eye brows and eyes on the detected image of a human head starts with the performing 610 of line cutting on the detected image of the human head to produce line cutting data. The line cutting is performed by the eyes detector 220 and the data produced is used for determining 620 whether the eye is present. Next, the line cutting data produced is compared 615 with predetermined line cutting instructions stored in the eye detector 220 to ascertain whether the image of an eye is present, and if so whether the eye is open or closed. If the eye is open, the location of the image of the eye is stored 635.

[0064] Referring to FIG. 7, the step of detecting 350 the iris of the eye starts with the performing 710 line cutting on the detected image of the open eye to produce iris line cutting data. Next, the iris line cutting data is compared with the iris line cutting database 255 and correlated to the iris direction database 265. The iris direction may then be determined 720 by looking up the iris direction database 265 which matches data in the iris line cutting database 255.

[0065] Referring to FIG. 9, the image of the eye 21 here shows the iris 26 at the right side of the eye 21. The boundary chain code 50b of the sclera in this example is HCEF. The iris line cutting data and the boundary chain code of the sclera is then

correlated and matched to the iris direction database 265 and the direction of the eye gaze may be determined to be looking at the left on the same level as the eye.

[0066] It will be appreciated that various modifications and improvements can be made by a person skilled in the art without departing from the scope of the present invention.

Claims

1. A method for detecting and determining gaze direction of individuals from a digital image comprising the steps:

a. detecting and locating possible image of human head from said digital image;

b. detecting and locating image of eyebrows and image of eye on detected image of human head;

c. determining boundary chain code of external boundary of sclera of said image of eye;

d. comparing said boundary chain code with eye boundary chain code database;

e. detecting iris of said image of eye; and

f. determining eye gaze direction of said image of eye.

2. The method in accordance with claim 1, wherein said step a. further comprises the steps:

a1. dividing digital image into predetermined number of sectors;

a2. computing color histogram of said predetermined number of sectors;

a3. comparing said color histogram for each of said predetermined number of sectors with said predetermined skin tone colors; and

a4. marking image region having said skin tone color as possible image of human head if said predetermined skin tone colors match said color histogram of each of said predetermined number of sectors.

3. The method in accordance with claim 1, prior to step b. comprises step g. of confirming said possible image of human head as a detected image of human head.

4. The method in accordance with claim 3, wherein said step g. further comprises the steps:

g1. segmenting said image region of marked possible image of human head;

g2. determining boundary chain code of external boundary of possible image of human head;

g3. comparing said boundary chain code of external boundary of possible human head with a head boundary chain code database; and

g4. confirming said possible image of human head as a detected image of human head.

5. The method in accordance with claim 1, wherein said step b. further comprises the steps:

b1. performing line cutting on said detected image of human head to produce eye line cutting data;

b2. comparing said eye line cutting data with a set of predetermined line cutting instructions;

b3. determining presence of an image of an eye;

b4. determining whether eye is open; and

b5. storing location of said image of said eye.

6. The method in accordance with claim 1, wherein said step f. further comprises the steps:

f1. performing line cutting on said detected image of eye to produce iris line cutting data;

f2. comparing said iris line cutting data with an iris line cutting database; and

f3. determining iris direction by looking up iris direction database.

7. The method in accordance with claim 1, wherein said digital image is a digitally captured color image.

8. A method for detecting and determining gaze direction of individuals from a digital image comprising the steps:

a. detecting and locating possible image of human head from said digital image;

b. detecting and locating image of eyebrows and image of eye on detected image of human head;

c. determining boundary chain code of external boundary of sclera of said image of eye;

d. calculating first difference of said boundary chain code to produce a first difference boundary chain code;

e. comparing said first difference boundary chain code with eye boundary chain code database;

f. detecting iris of said image of eye; and

g. determining eye gaze direction of said image of eye.

9. The method in accordance with claim 8, wherein said step a. further comprises the steps:

a1. dividing digital image into predetermined number of sectors;

a2. computing color histogram of said predetermined number of sectors;

a3. comparing said color histogram for each of said predetermined number of sectors with said predetermined skin tone colors; and

a4. marking image region having said skin tone color as possible image of human head if said predetermined skin tone colors match said color histogram of each of said predetermined number of sectors.

10. The method in accordance with claim 8, prior to step b. comprises step h. of confirming said possible image of human head as a detected image of human head.

11. The method in accordance with claim 10, wherein said step h. further comprises the steps:

h1. segmenting said image region of marked possible image of human head;

h2. determining boundary chain code of external boundary of possible image of human head;

h3. comparing said boundary chain code of external boundary of possible human head with a head boundary chain code database; and

h4. confirming said possible image of human head as a detected image of human head.

12. The method in accordance with claim 8, wherein said step b. further comprises the steps:

b1. performing line cutting on said detected image of human head to produce eye line cutting data;

b2. comparing said eye line cutting data with a set of predetermined line cutting instructions;

b3. determining presence of an image of an eye;

b4. determining whether eye is open; and

b5. storing location of said image of said eye.

13. The method in accordance with claim 8, wherein said step d. further comprises the steps:

d1. obtaining numerical difference between each letter of said boundary chain code;

d2. assigning a running number to each letter of a chain code representation;

d3. matching said numerical difference to said running number and consequently said letter of said chain code representation; and

d4. forming said first difference boundary chain code by obtaining said matching letter of said chain code representation.

14. The method in accordance with claim 8, wherein said step g. further comprises the steps:

g1. performing line cutting on said detected image of eye to produce iris line cutting data;

g2. comparing said iris line cutting data with an iris line cutting database; and

g3. determining iris direction by looking up iris direction database.

15. The method in accordance with claim 8, wherein said digital image is a digitally captured color image.

16. A method for detecting and determining gaze direction of individuals from a digital image comprising the steps:

a. detecting and locating possible image of human head from said digital image;

b. detecting and locating image of eyebrows and image of eye on detected image of human head;

c. determining boundary chain code of external boundary of sclera of said image of eye;

d. calculating first difference of said boundary chain code to produce a first difference boundary chain code;

e. calculating normalized first difference boundary chain code from said first difference boundary chain code;

f. comparing said normalized first difference boundary chain code with eye boundary chain code database;

g. detecting iris of said image of eye; and

h. determining eye gaze direction of said image of eye.

17. The method in accordance with claim 16, wherein said step a. further comprises the steps:

a1. dividing digital image into predetermined number of sectors;

a2. computing color histogram of said predetermined number of sectors;

a3. comparing said color histogram for each of said predetermined number of sectors with said predetermined skin tone colors; and

a4. marking image region having said skin tone color as possible image of human head if said predetermined skin tone colors match said color histogram of each of said predetermined number of sectors.

18. The method in accordance with claim 16, prior to step b. comprises step i. of confirming said possible image of human head as a detected image of human head.

19. The method in accordance with claim 18, wherein said step i. further comprises the steps:

i1. segmenting said image region of marked possible image of human head;

i2. determining boundary chain code of external boundary of possible image of human head;

i3. comparing said boundary chain code of external boundary of possible human head with a head boundary chain code database; and

i4. confirming said possible image of human head as a detected image of human head.

20. The method in accordance with claim 16, wherein said step b. further comprises the steps:

b1. performing line cutting on said detected image of human head to produce eye line cutting data;

b2. comparing said eye line cutting data with a set of predetermined line cutting instructions;

b3. determining presence of an image of an eye;

b4. determining whether eye is open; and

b5. storing location of said image of said eye.

21. The method in accordance with claim 16, wherein said step d. further comprises the steps:

d1. obtaining numerical difference between each letter of said boundary chain code;

d2. assigning a running number as a representation of each letter of a chain code representation;

d3. matching said numerical difference to said running number and consequently said letter of said chain code representation; and

d4. forming said first difference boundary chain code by obtaining said matching letter of said chain code representation.

22. The method in accordance with claim 16, wherein said step e. further comprises the step:

e1. identifying lowest integer of said representation of said first difference boundary chain code;

e2. rotating said representation of said letters of said first difference chain code representation prior to said lowest integer to the rear of said representation of said first difference boundary chain code to produce a new representation of said first difference boundary chain code for all possible occurrences if lowest integer occurs more than once; and

e3. select numerically lowest of said new representations as the normalized first difference boundary chain code.

23. The method in accordance with claim 16, wherein said step h. further comprises the steps:

h1. performing line cutting on said detected image of eye to produce iris line cutting data;

h2. comparing said iris line cutting data with an iris line cutting database; and

h3. determining iris direction by looking up iris direction database.

24. The method in accordance with claim 16, wherein said digital image is a digitally captured image.

25. An image processing system for determining gaze direction of individuals from a digital image comprising:

a head detector for detecting a possible image of a human head from said digital image;

a head boundary processor for determining a boundary chain code of said possible image of said human head;

an eye detector for detecting image of eye of detected image of said human head by performing line cutting techniques producing eye line cutting data;

an eye boundary processor for determining a boundary chain code of external boundary of sclera of said detected image of eye;

an eye boundary chain code database for storing a plurality of eye boundary chain codes;

an eye boundary chain code comparator for comparing said boundary chain code of sclera with said plurality of eye boundary chain codes;

an iris detector for detecting image of iris of said detected image of eye by performing line cutting techniques producing iris line cutting data;

an iris direction database for storing a plurality of iris direction data; and

an iris direction determinator for determining the gaze direction of said image of iris by comparing results from comparision of said iris line cutting data from said iris detector and said iris line cutting database.

26. The image processing system in accordance with claim 25, wherein said system further comprises:

a head boundary chain code database for storing a plurality of chain codes and for comparing with said boundary chain code of said possible image of said human head for confirming a detected image of said human head.

27. The image processing system in accordance with claim 25, wherein said eye detector further comprises:
a plurality of eye line cutting instructions for comparing with said eye line cutting data.

28. An image processing system for determining gaze direction of individuals from a digital image comprising:

a head detector for detecting a possible image of a human head from said digital image;

a head boundary processor for determining a boundary chain code of said possible image of said human head;

an eye detector for detecting image of eye of detected image of said human head by performing line cutting techniques producing eye line cutting data;

an eye boundary processor for determining a boundary chain code of external boundary of sclera of said detected image of eye;

a first difference processor for calculating a first difference boundary chain code from said boundary chain code of external boundary of sclera of said detected image of eye;

an eye boundary chain code database for storing a plurality of eye boundary chain codes;

an eye boundary chain code comparator for comparing said first difference boundary chain code with said plurality of eye boundary chain codes;

an iris detector for detecting image of iris of said detected image of eye by performing line cutting techniques producing iris line cutting data;

an iris direction database for storing a plurality of iris direction data; and

an iris direction determinator for determining the gaze direction of said image of iris by comparing results from comparision of said iris line cutting data from said iris detector and said iris line cutting database.

29. The image processing system in accordance with claim 28, wherein said system further comprises:

a head boundary chain code database for storing a plurality of chain codes and for comparing with said boundary chain code of said possible image of said human head for confirming a detected image of said human head.

30. The image processing system in accordance with claim 28, wherein said eye detector further comprises:

a plurality of eye line cutting instructions for comparing with said eye line cutting data.

31. An image processing system for determining gaze direction of individuals from a digital image comprising:

a head detector for detecting a possible image of a human head from said digital image;

a head boundary processor for determining a boundary chain code of said possible image of said human head;

an eye detector for detecting image of eye of detected image of said human head by performing line cutting techniques producing eye line cutting data;

an eye boundary processor for determining a boundary chain code of external boundary of sclera of said detected image of eye;

a first difference processor for calculating a first difference boundary chain code from said boundary chain code of external boundary of sclera of said detected image of eye;

a normalized first difference processor for calculating a normalized first difference boundary chain code from said first difference boundary chain code;

an eye boundary chain code database for storing a plurality of eye boundary chain codes;

an eye boundary chain code comparator for comparing said normalized first difference boundary chain code with said plurality of eye boundary chain codes;

an iris detector for detecting image of iris of said detected image of eye by performing line cutting techniques producing iris line cutting data;

an iris direction database for storing a plurality of iris direction data; and

an iris direction determinator for determining the gaze direction of said image of iris by comparing results from comparision of said iris line cutting data from said iris detector and said iris line cutting database.

32. The image processing system in accordance with claim 31, wherein said system further comprises:

a head boundary chain code database for storing a plurality of chain codes and for comparing with said boundary chain code of said possible image of said human head for confirming a detected image of said human head.

33. The image processing system in accordance with claim 31, wherein said eye detector further comprises:

a plurality of eye line cutting instructions for comparing with said eye line cutting data.