



METHOD AND APPARATUS FOR OPTICAL CHARACTER RECOGNITION

Field of the Invention

5 The present invention relates to optical character recognition, and more particularly to optical character recognition of characters on license plates of vehicles.

Background of the Invention

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License plate recognition (LPR) systems are known, and essentially comprise a vision system to capture an image of either the front or rear of a vehicle, or both, which includes the vehicle's license plate, and provide the captured image; and an image processing system for
15 locating the license plate in the captured image, determining the characters on the license plate, and providing the characters for further post processing. Such post processing is dependent on the application of the LPR, and in a typical car parking application; the post processing can include logging time of entry and departure of vehicles, and
20 computation of parking charges due.

The captured image or frame comprises a matrix of picture elements or pixels, which are stored in a semiconductor memory, typically random access memory, in the image processing system. The data in relation to each pixel i.e. pixel data can be accessed, and in this
25 way, a software program can be used to assess the data of the pixels of the captured image, and based on a predetermined algorithm, such as are known in the art, the program can locate the cluster of pixels that constitute the image of the license plate. The pixel data of each pixel includes information on the pixel's location, and an indication of the
30 intensity level of the pixel i.e. the extremes of light or dark, or levels therebetween.



Upon identifying the cluster of pixels of the license plate i.e. the license plate cluster in the captured image, the next step is to determine the character pixel clusters of each character on the license plate, where each character pixel cluster comprises a group of pixels that provide an image of a particular character. Again, with the particular knowledge of the arrangement of characters on a license plate in a particular country, a software program can determine the specific character pixel clusters that constitute each of the characters on the license plate.

The following step is to identify the characters from each of the character pixel clusters. Known methods of performing such character recognition include boundary tracing of a character pixel cluster using chain codes, and computing intensive processing including artificial intelligence to identify the characters. Due to the inherent short time within which a license plate needs to be recognized in a practical LPR system, prior art systems require higher performance computing platforms than that of a desktop computer, such as an Intel® Pentium® power machine. Indeed, in some systems dedicated digital signal processors (DSP) may be employed.

Brief Summary of the Invention

The present invention seeks to provide a method and apparatus for optical character recognition, which overcomes or at least reduces the abovementioned problems of the prior art.

Accordingly, in one aspect, the present invention provides a method for identifying one of a plurality of predetermined characters from a character pixel cluster, the method comprising:

- a) determining external character features in the character pixel cluster;
- b) determining internal character features in the character pixel cluster;

c) comparing the external character features and the internal character features in the character pixel cluster with predetermined internal and external character features of each of the plurality of predetermined characters; and

- 5 d) identifying the one of the plurality of predetermined characters in the character pixel cluster when the external and internal character features of the one of the plurality of predetermined characters are substantially similar to the external and internal character features in the character pixel cluster.

10 In another aspect the present invention provides an apparatus for identifying one of a plurality of predetermined characters from a character pixel cluster, the apparatus comprising:

an input for receiving the character pixel cluster;

15 a boundary processor for receiving the character pixel cluster and providing a boundary chain code;

a character boundary chain code database for storing a plurality of boundary chain codes and a plurality of candidate characters associated therewith;

20 a character boundary chain code comparator coupled to receive the boundary chain code and coupled to the character boundary chain code database, the character boundary chain code comparator having an output for providing at least two of the plurality of candidate characters;

25 a line-cutting instruction database for storing the plurality of candidate characters and a plurality of line-cutting instructions associated therewith,

30 a line-cutting determinator coupled to receive the at least one of the plurality of candidate characters, the line-cutting determinator for accessing the line-cutting instruction database and for providing at least one of the plurality of line-cutting instructions associated with the at least one of the plurality of candidate characters;

a line-cutting processor coupled to receive the at least one of the plurality of line-cutting instructions and the character pixel cluster, the line-cutting processor for performing the at least one of the plurality of line-cutting instructions, and the line-cutting processor for providing
5 line-cutting data;

a character identification database for storing a plurality of line-cutting data and the plurality of predetermined characters associated therewith; and

a line-cutting data comparator coupled to receive the line-cutting data and coupled to access the character identification database, the line-cutting data comparator for comparing the line-cutting data with the plurality of line-cutting data, and for providing one of the plurality of characters as the identified one of the plurality of predetermined characters at an output.
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Brief Description of the Drawings

An embodiment of the present invention will now be more fully described, by way of example, with reference to the drawings of which:

20 FIG. 1 shows elements of a typical license plate recognition system;

FIG. 2 shows a frame of a captured image obtained by the license plate recognition system in FIG. 1;

FIG. 3 shows an enlarged view of the license plate portion of the captured image in FIG.2;

25 FIG. 4 shows a functional block diagram of an optical character recognition system in accordance with the present invention that operates in the license plate recognition system in FIG. 1;

FIG. 5 shows a flowchart detailing the operation of the optical character recognition system in FIG. 4;

30 FIG. 6A and 6B shows an enlarged view of a character pixel cluster of the number 0 that is provided to the optical character recognition system in FIG. 4; and

FIG. 7A and 7B shows an enlarged view of a character pixel cluster of the number 8 that is provided to the optical character recognition system in FIG. 4.

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Detail Description of the Drawings

A character recognition system in accordance with the present invention first uses a boundary tracing process to determine external character features in the form of an outline of a character pixel cluster. Then, a subsequent selective line-cutting process of the character pixel cluster is performed to determine internal character features that identify the particular character represented by the character pixel cluster. A chain code derived from the character pixel cluster by the boundary tracing process is used to determine a representation of the outline of the character pixel cluster. The chain code is then used to identity candidate characters. When there is more than one candidate character associated with the chain code, then predetermined line-cutting instructions associated with the candidate characters are applied to the character pixel cluster. The line-cutting results are subsequently compared with possible outcomes for the candidate characters, and one of the candidate characters is identified.

As this character recognition system employs external boundary tracing using chain codes and line cutting, which are relative easy to process in a computer, the present invention can advantageously be performed with an ordinary desktop computer, such as an Intel® Pentium® powered machine and the like.

With reference to FIG. 1, a typically LPR system 100 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 a 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 frame grabber 120 comprises an IC-ASYNC gray scale frame grabber card manufactured by Coreco Imaging Inc. of Canada.

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 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.

With reference to FIG. 2 the LPR system 100 initially captures an image 200 of the front of a vehicle, where the captured image includes the vehicle's license plate, as shown. The captured image has a frame size of 768 by 578 pixels, and has a resolution of 8 bits per pixel. The image can be captured, for example, when the vehicle is detected approaching an entry gantry of a car park.

With reference to FIG. 3 the LPR 100 system then determines the location of the license plate on the captured image, and identifies a portion 300 of the captured image 200 that includes the license plate. The portion 300 of the captured image 200 is 520 by 160 pixels in size, and the pixel cluster of the license plate i.e. the license plate pixel cluster size 310 is 230 by 48 pixel.

Processes known to one skilled in the art are then applied to the license plate pixel cluster 310, to identify character pixel clusters 315-

322 of the characters in the license plate pixel cluster 310. Each of the character pixel clusters 315-322 is then made available for character recognition processing.

With reference to FIG. 4, a functional representation 400 of the image processing system 110 comprises an input 405 for receiving a character pixel cluster 410. The input 405 is coupled to a boundary processor 415 that performs a boundary tracing process on the character pixel cluster 410 and provides a boundary chain code 420 or external boundary chain code. A character boundary chain code comparator 425 has a first input that is coupled to receive the boundary chain code 420, a second input that is coupled to a character boundary chain code database 430, and a third output that is coupled to the output 480 to provide an identified character 475. The boundary chain code 420 represents external character features or an external character boundary of a character in the character pixel cluster 410, where the character is one of a predetermined or pre-selected group of characters.

The character boundary chain code database 430 stores a variety of candidate character(s) associated with each of the boundary chain codes. A particular boundary chain code comprises a number of external character boundary pixels, can be uniquely associated with a particular character. Hence, detecting the particular boundary chain code allows the particular character to be identified without the need for further processing. In such an instance, the identified character 475, is then provided by the character boundary chain code comparator 425 directly to the output 480. This operation applies for characters 5, 6, L, P, T, Z, K, N, R, V and X.

However, some boundary chain codes are associated with more than one character, which are referred to as candidate characters 435. Such is the case for the candidate characters 0 and 8, 1 and 4, 7 and 9, J and U, C and G, and M and W.

TABLE 1 below provides the various boundary chain codes and the associated character(s) that are stored in the character boundary chain code database 430. The boundary chain code column lists the various valid boundary chain codes; the type column indicates whether chain code 4 i.e. A, C, E and G is used, or chain code 8 i.e. A-H is used, for the particular boundary chain code. The character columns indicate the character(s) associated with the particular boundary chain codes listed in the boundary chain code column.

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Chain code	Type	Candidate character(s)	
GACE	4	0	8
GCE	4	1	4
GAGCE	4	7	9
GACGEC	4	J	U
GACECAE	4	C	G
.....FD	8	M	W
GAGEACECAE	4	5	
GACECAE	4	6	
GAEC	4	L	
GCACE	4	P	
AGCAE	4	T	
AGAECE	4	Z	
GCHDBF	8	K	
GCHCGD	8	N	
GCHDBDE	8	R	
HBCFD	8	V	
HFBHDBFD	8	X	

TABLE 1

The character boundary chain code comparator 425 compares the boundary chain code 420 with the variety of boundary chain codes in the character boundary chain code database 430; determines when candidate characters 435 are associated with the boundary chain code 420, and provides the candidate characters 435 to a line-cutting determinator 440. The line cutting determinator 440 has a first input

coupled to receive the candidate characters 435, and a second input coupled to a line-cutting instruction database 445.

The line-cutting instruction database 445 stores particular candidate character associated a particular boundary chain code, and also stores corresponding predetermined line-cutting instructions associated with the particular boundary chain code and the particular candidate characters. Hence, when there is more than one candidate character 435, the line-cutting determinator 440 uses the candidate character 435 to search the line-cutting instruction database 445 to locate the corresponding line-cutting instruction 450; and then provides the line-cutting instruction 450 to a line-cutting processor 455.

TABLE 2 below provides the various candidate characters and the associated line-cutting instructions that are stored in the line-cutting instruction database 445. The candidate characters column lists the various candidate characters; and the line-cutting instructions column indicates particular line-cutting instructions associated with the particular candidate characters listed in the candidate characters column.

Candidate characters		Line-cutting instructions
0	8	Central vertical line
1	4	Central horizontal line
7	9	1 st quarter horizontal lines from the top
J	U	Central horizontal line
C	G	Central vertical line
M	W	1 st and 3 rd quarter horizontal lines from the top

TABLE 2

The line-cutting processor 455 receives the line-cutting instruction 450, and is also coupled to receive the character pixel cluster 410 from the input 405. The line-cutting processor 455 then performs the line-cutting instruction 450 on the character pixel cluster 410, and provides

line-cutting data 460 to a line-cutting data comparator 465. The line cutting data 460 comprises line-cutting results. In effect, when the line-cutting processor 455 performs the line-cutting instruction 450, it identifies the particular line of pixels of the character pixel cluster 410, which forms the specified “cutting line”, in accordance with the line-cutting instruction 450. The line-cutting processor 455, then determines if any of the pixels of the line of pixels in the character pixel cluster 410, constitute pixels that are part of the character. When this is detected, such an occurrence is referred to as a “line cut” or simply “cut”.

The line-cutting data comparator 465 is coupled to receive the line-cutting data 460 and is coupled to access a character identification database 470. The character identification database 470 stores particular candidate characters associated with particular boundary chain codes, stores corresponding predetermined line-cutting data 460 associated with the candidate characters, and stores particular identified characters. Hence, the line-cutting data comparator 465 uses the line-cutting data 460 and searches the line-cutting data in the character identification database 470 to locate a corresponding identified character 475. Upon locating the corresponding identified character 475, the line-cutting data comparator 465 provides the identified character 475 to the output 480.

TABLE 3 below provides the various candidate characters, the associated line-cutting data, and associated identified characters that are stored in the character identification database 470. The candidate characters column lists the various candidate characters; the line-cutting data column indicates particular line-cutting results, or cuts, associated with the particular candidate character listed in the candidate characters column, and the identified character column indicates the corresponding identified characters.

Candidate Characters		Line-cutting data (No. of cuts)	Identified character
0	8	4	0
		6	8
1	4	2	1
		4	4
7	9	2	7
		4	9
J	U	2	J
		4	U
C	G	4	C
		6	G
M	W	Top outer width is equal or less than the bottom outer width	M
		Top outer width is not equal or less than the bottom outer width	W

TABLE 3

5 With reference to FIG. 5 the operation 500 of the image processing system 110 starts 505 with monitoring 510 the input 405 for receipt of a character pixel cluster. When the character pixel cluster 410 is received, the boundary processor 415 determines the external character features, by determining 515 the boundary chain code 420 from the character pixel cluster 410. The character boundary chain code comparator 425 then compares the boundary chain code 420 with the various possible boundary chain codes in the character boundary chain code database 430.

15 When the character boundary chain code comparator 425 finds the boundary chain code 420 in the character boundary chain code database 430, the character boundary chain code comparator 425 then determines the corresponding candidate character(s) associated with the boundary chain code 420. When the character boundary chain code comparator 425 determines 525 that there is one corresponding character associated with the boundary chain code 420, then the identified character 475 is provided 545 at the output 480 by the

character boundary chain code comparator 425. However, when the character boundary chain code comparator 425 determines 525 that there is more than one corresponding character associated with the boundary chain code 420, the candidate characters 435 are provided to
 5 the line-cutting determinator 440.

The line-cutting determinator 440 determines 530 the predetermined line-cutting instructions 450 associated with the candidate characters 435 from the line-cutting instructions database 445, and provides the line-cutting instructions 450 to the line cutting
 10 processor 455. This is to determine the internal character features of the character pixel cluster 410. After the line cutting processor 455 performs 535 the line-cutting instructions 450 on the character pixel cluster 410, the line cutting processor 455 provides the line-cutting data 460 to the line-cutting data comparator 465. Using the line-cutting
 15 data 460 the line-cutting data comparator 465 accesses the character identification database 470 and compares 540 the line-cutting data 460 with predetermined line-cutting data therein. Upon locating the line-cutting data 460 in the character identification database 470, the line-cutting data comparator 465 determines the corresponding identified
 20 character 475 associated with the line-cutting data 460, and provides 545 the identified character 475 to the output 480.

The operation 500 then returns to monitoring 510 receipt of the next character pixel cluster, and proceeds as described above.

With reference to FIGS. 6A and 6B recognition of the number 0
 25 from a character pixel cluster 410A, in accordance with the present invention, will now be described.

When the pixel cluster 410A is received 510, the boundary processor 415 determines 515 a boundary chain code 420A from the character pixel cluster 410A. This is accomplished by first identifying
 30 boundary pixels, marked with an "X", and then, starting at the top left hand most boundary pixel 601 [Type 4 chain Code, with ACEG], tracing the path of boundary pixels using the chain code directional reference

605 and the number of pixels aligned in each of the directions. Hence, the resulting chain code is:

G3,E,G7,E,G4,E,G2,A2,G2,A,G4,A3,G,A6,C,A3,C3,A,C13,E,C5,E,C,E,C,
E3,C,E2,G,E4,G,E

5 A minimum count of three pixels is set as the resolution for any of the directions. This means that only the directional links having at least three pixels are considered, and those having less than three pixels are ignored. Applying this to the chain code above results in the following chain code:

10 G1,G2,G1,G1,A1,A2,A1,C1,C4,C1,E1,E1

Adding up the direction links above produces the chain code:

G5,A4,C6,E2

Dropping the units from the chain code above produces the resultant boundary chain code 420A below:

15 GACE

When the character boundary chain code comparator 425 compares 520 the boundary chain code GACE (420A) with the various possible boundary chain codes in the character boundary chain code database 430, it is determined from the character boundary chain code database 430, as indicated in TABLE 1, that the numbers 0 and 8 are the corresponding candidate characters 435A.

20 Upon receiving the candidate characters 0 and 8 (435A), the line-cutting determinator 440, determines 530 the line-cutting instruction "Central vertical line" (450A) from the line-cutting instruction database 445, as indicated in TABLE 2, using the candidate characters 0 and 8 (435A). The line-cutting instruction "Central vertical line" (450A) is subsequently performed 535 on the character pixel cluster 410A by the line-cutting processor 455 and provides line-cutting data 460A.

30 Referring to FIG. 6B, the line-cutting processor 455 passes a central vertical line 650 through the character pixel cluster 410A, and identifies the boundary pixels 651-654 through which the central

vertical line 650 passes. The pixels 651-654 comprises four pixels, hence, the line-cutting data 460A indicates 4 cuts.

The line-cutting data comparator 465 receives the line-cutting data 460A indicating 4 cuts, and determines from a comparison 540 of the line-cutting data in the character identification database 470, as indicated in TABLE 3, that the character is the number 0. The line-cutting data comparator 465 then provides 545 the number 0 as the identified character 475 at the output 480.

With reference to FIGS. 7A and 7B recognition of the number 8 from a character pixel cluster 410B, in accordance with the present invention, will now be described.

When the pixel cluster 410B is received 510, the boundary processor 415 determines 515 a boundary chain code 420B from the character pixel cluster 410B. This is accomplished by first identifying boundary pixels, marked with an "X", and then, starting at the top left hand most boundary pixel 701, tracing the path of boundary pixels using the same chain code directional reference 605 (Type 4, with A C E G) and the number of pixels aligned in each of the directions. Hence, the resulting chain code is:

G2,E,G8,A,G3,E,G7,A,G2,A,G2,A8,C,A,C,A2,C3,A,C5,E,C5,A,C3,E,C5,E,
C,E,C,E9,G,E

As before, the minimum count of three pixels is set as the resolution for any of the directions. Applying this to the chain code above results in the following chain code:

G2,G,G2,A2,C,C,C,C,C,E3

Adding up the direction links above produces the chain code:

G5,A2,C5,E3

Dropping the units from the chain code above produces the resultant boundary chain code 420B below:

GACE

Note that this is same boundary chain code 420A of the number 0, which was determined above. When the character boundary chain code

comparator 425 compares 520 the boundary chain code GACE (420B) with the various possible boundary chain codes in the character boundary chain code database 430, it is determined from the character boundary chain code database 430, as indicated in TABLE 1, that the
5 numbers 0 and 8 are the corresponding candidate characters 435B.

Upon receiving the candidate characters 0 and 8 (435B), the line-cutting determinator 440, determines 530 the line-cutting instruction "Central vertical line" (450B) from the line-cutting instruction database 445, as indicated in TABLE 2, using the candidate characters 0 and 8
10 (435B). The line-cutting instruction "Central vertical line" (450B) is subsequently performed 535 on the character pixel cluster 410B by the line-cutting processor 455 and provides line-cutting data 460B.

Referring to FIG. 7B, the line-cutting processor 455 passes a central vertical line 750 through the character pixel cluster 410B, and
15 identifies the boundary pixels 751-756 through which the central vertical line 750 passes. The pixels 751-756 comprises six pixels, hence, the line-cutting data 460B now indicates 6 cuts.

The line-cutting data comparator 465 receives the line-cutting data 460B indicating 6 cuts, and determines from a comparison 540 of the
20 line-cutting data in the character identification database 470, as indicated in TABLE 3, that the character is the number 8. The line-cutting data comparator 465 then provides 545 the number 8 as the identified character 475 at the output 480.

The optical character recognition system of the present invention
25 as described, can advantageously be performed with an ordinary desktop computer, such as an Intel® Pentium® powered machine and the like.

This is accomplished by applying an external boundary tracing process using chain codes on a character pixel cluster to determine
30 external features of the character pixel cluster, and then applying a line-cutting process on the character pixel cluster to determine internal features of the character pixel cluster. The results from these processes,

when compared with the known external and internal features of a predetermined number of characters, allowing a character among the predetermined number of characters, to be identified.

Thus, the present invention, as described provides a method and
5 apparatus for optical character recognition, which overcomes or at least reduces the abovementioned problems of the prior art.

It will be appreciated that although only particular embodiments of the invention have been described in detail, various modifications and improvements can be made by a person skilled in the art without
10 departing from the scope of the present invention.

Claims

1. A method for identifying one of a plurality of predetermined characters from a character pixel cluster, the method comprising:
 - 5 a) determining external character features in the character pixel cluster;
 - b) determining internal character features in the character pixel cluster;
 - c) comparing the external character features and the internal
 - 10 character features in the character pixel cluster with predetermined internal and external character features of each of the plurality of predetermined characters; and
 - d) identifying the one of the plurality of predetermined characters in the character pixel cluster when the external and internal character
 - 15 features of the one of the plurality of predetermined characters are substantially similar to the external and internal character features in the character pixel cluster.
2. A method in accordance with claim 1, wherein a plurality of
- 20 external character boundaries that are associated with the plurality of predetermined characters, and wherein step (a) comprises the step of determining one of the plurality of external character boundaries in the character pixel cluster is associated with at least one of the plurality of predetermined characters.
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3. A method in accordance with claim 2, wherein step (a) comprises the steps of:
 - a1) determining a plurality of external character boundary
 - pixels that form one of the plurality of external character boundaries in
 - 30 the character pixel cluster; and
 - a2) determining relative positions of adjacent external boundary pixels of the plurality of external character boundary pixels,

wherein the relative positions of the adjacent external character boundary pixels is substantially indicative of the external character boundary of the at least one of the plurality of predetermined characters in the character pixel cluster.

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4. A method in accordance with claim 3, wherein step (a1) comprises the step of determining intensity level of each of the plurality of external character boundary pixels is greater than a predetermined pixel intensity level.

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5. A method in accordance with claim 4, prior to step (a1), comprises the step of determining the predetermined pixel intensity level from at least some pixels adjacent to the each of the plurality of external character boundary pixels.

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6. A method in accordance with claim 3, wherein step (a1) comprises the step of determining contrast level of each of the plurality of external character boundary pixels is greater than a predetermined pixel contrast level.

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7. A method in accordance with claim 6, prior to step (a1), comprises the step of determining the predetermined pixel contrast level from at least some pixels adjacent to the each of the plurality of external character boundary pixels.

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8. A method in accordance with claim 3, wherein step (a2) comprises the step of determining a chain code of at least some of the plurality of external character boundary pixels.

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9. A method in accordance with claim 3, wherein the internal features comprise a plurality of internal character boundary pixels, wherein step (b) comprises the steps of:

b1) detecting the plurality of internal character boundary pixels in the character pixel cluster; and

b2) identifying at least one of a plurality of predetermined arrangements of pixels in the character pixel cluster, wherein the at least one of the plurality of predetermined arrangements of pixels includes at least one of the plurality of external character boundary pixels and at least one of the plurality of internal character boundary pixels, and wherein the at least one of the plurality of predetermined arrangements of pixels is associated with the at least one of the plurality of predetermined characters.

10. A method in accordance with claim 9, wherein step (b1) comprises the step of determining intensity level of each of the plurality of internal boundary pixels is greater than a predetermined intensity level.

11. A method in accordance with claim 10, prior to step (b1), comprises the step of determining the predetermined intensity level from at least some pixels adjacent to the each of the plurality of internal boundary pixels

12. A method in accordance with claim 9, wherein step (b1) comprises the step of determining contrast level of each of the plurality of external boundary pixels is greater than a predetermined contrast level.

13. A method in accordance with claim 12, prior to step (b1) comprises the step of determining the predetermined contrast level from at least some pixels adjacent to the each of the plurality of external boundary pixels

14. A method in accordance with claim 9, wherein step (b2) comprises the step of determining that the one of the plurality predetermined arrangements of pixels includes the at least one of the plurality of external character boundary pixels.

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15. A method in accordance with claim 14, wherein step (b2) comprises the step of determining that the one of the plurality of predetermined arrangements of pixels includes the at least one of the plurality of internal character boundary pixels.

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16. A method in accordance with claim 14, wherein the one of the plurality of predetermined arrangements of pixels comprises a linear arrangement of pixels extending through the character pixel cluster, and wherein step (b2) comprises determining that the linear
15 arrangement of pixels includes the at least one of the plurality of external character boundary pixels, and determining that the linear arrangement of pixels includes the at least one of the plurality of internal character boundary pixels.

20 17. A method in accordance with claim 9, wherein step (c) comprises the steps of:

- c1) determining the one of the plurality of external character boundaries in the character pixel cluster is associated with at least one of the plurality of predetermined characters;
- 25 c2) determining the at least one of the plurality of predetermined arrangements of pixels in the character pixel cluster is associated with the at least one of the plurality of predetermined characters; and
- c3) determining one of a plurality of predetermined arrangement data from the at least one of the plurality of predetermined arrangements of
30 pixels in the character pixel cluster.

18. A method in accordance with claim 17, wherein the plurality of predetermined arrangement data is associated with the plurality of predetermined characters, and wherein step (d) comprises identifying the one of the plurality of predetermined characters in the character pixel cluster when the one of the plurality of predetermined arrangement data is associated with the one of the plurality of predetermined characters.

19. An apparatus for identifying one of a plurality of predetermined characters from a character pixel cluster, the apparatus comprising:

- an input for receiving the character pixel cluster;
- a boundary processor for receiving the character pixel cluster and providing a boundary chain code;
- a character boundary chain code database for storing a plurality of boundary chain codes and a plurality of candidate characters associated therewith;
- a character boundary chain code comparator coupled to receive the boundary chain code and coupled to the character boundary chain code database, the character boundary chain code comparator having an output for providing at least two of the plurality of candidate characters;
- a line-cutting instruction database for storing the plurality of candidate characters and a plurality of line-cutting instructions associated therewith,
- a line-cutting determinator coupled to receive the at least one of the plurality of candidate characters, the line-cutting determinator for accessing the line-cutting instruction database and for providing at least one of the plurality of line-cutting instructions associated with the at least one of the plurality of candidate characters;
- a line-cutting processor coupled to receive the at least one of the plurality of line-cutting instructions and the character pixel cluster, the line-cutting processor for performing the at least one of the plurality

line-cutting instructions, and the line-cutting processor for providing line-cutting data;

a character identification database for storing a plurality of line-cutting data and the plurality of predetermined characters associated therewith; and

a line-cutting data comparator coupled to receive the line-cutting data and coupled to access the character identification database, the line-cutting data comparator for comparing the line-cutting data with the plurality of line-cutting data, and for providing one of the plurality of characters as the identified one of the plurality of predetermined characters at an output.

20. An apparatus in accordance with claim 19 wherein the character boundary chain code comparator further comprises another output for providing one of the plurality of candidate characters when the character boundary chain code comparator determines that only the one of the plurality of candidate characters is associated with the received boundary chain code, wherein the another output of the character boundary chain code comparator is coupled to the output.