

Method and apparatus for OCR reading a digit-display meter

TECHNICAL FIELD

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[001] This invention concerns an optical recognition method for characters of a character set, particularly a numerical set, such as that running continuously in a digit display of a utility meter (e.g. a watt-hour meter). The method of our invention enables our optical character recognition (OCR) to
10 learn to recognize the complete character set. The apparatus disclosed herein implements that method and enables it to be adapted to read a utility meter's digit display.

15 BACKGROUND ART

[002] Despite the advent of supervisory control and data acquisition (SCADA) technologies it is still necessary to obtain readings of various types of meters scattered over a large or located in a remote area. This is especially
20 true for utility meters such as the electric meters (also known as electricity consumption meter or watt-hour meter) for consumption recording and billing purposes. It may also be necessary to measure other electric parameters such as voltage, current or power for monitoring or control purposes.

[003] While there are electronic electric meters such as that disclosed in U.S. Patent No. 6,538,577 (Ehrke) that enables the electric meter to be automatically and remotely read in a network such as local area network (LAN) or wide area network (WAN), many of the electric meters still in used today are
5 the older analog meters having dials or digit-display. Reading such meters still require human effort and is therefore labour intensive and time-consuming besides the readings being susceptible to human error. Most of these analog meters are very reliable and durable, lasting for decades and thus it may be too disruptive and uneconomical to replace them with digital electronic ones.

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[004] As such, there arise methods and devices for reading these analog meters automatically and remotely. To read an analog meter with dial display, the reader device only needs to recognise the position of the dial hand such as that disclosed in U.S. Patent No. 5,559,894 (Lubliner *et al.*). To read an analog
15 meter with digit display, the reader device has to contend with varying font types and size using conventional optical character recognition (OCR) methods.

[005] Camera-based computer vision system has been used to solve this
20 problem in a way similar to vehicle registration plate recognition. An OCR algorithm may be applied to automatically recognise images captured of a digit display of an analog meter. There are many disadvantages of such conventional OCR such as requiring the camera for capturing images to be recognised to be installed in good pose and orientation. Often, the camera

needs to be mounted tilted so as not to totally obstruct visual access to the digit display for manual visual inspection. Moreover, if the lighting is not good, the image captured may not be of sufficient quality for successful character recognition.

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[006] Another difficult aspect of conventional OCR methods is recognizing the different fonts and font sizes used in the different meters. The OCR algorithm thus has to be pre-trained with the specific font library used in the meter; otherwise, the recognition rate may be unacceptably low. Often, in the same meter's digit display, different font size may be used. For example, the last digit, usually the decimal digit, is often provided in a smaller font size and calibrated with sub-unit lines which may be captured along by the OCR and complicate recognition.

15 [007] A further problem posed by the last digit, being the fastest moving digit as the meter is running, often displays a reading between two digits, for example, as shown in FIGURE 1, between "4" and "5". In such situations, conventional OCR algorithm will usually fail.

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SUMMARY OF DISCLOSURE

[008] We have now proposed a new vision-based character recognition method for automatically and accurately reading characters of a character set

appearing as digit display in, for example, utility meter. Our proposed method does not require our algorithm to preselect the correct font and font size and be pre-trained to recognise the characters in the preselected font. In fact, our method enables learning "on-the-fly" of the character set used in the meter display.

[009] Our method also does not require the camera to be installed in a prescribed position nor require a certain lighting ambience for best image capture. Using our algorithm, tilted or distorted images captured will not affect the accuracy of our reading. As such, it is more robust and accurate against environmental changes or fluctuations in respect of the meter's surrounding such as ambience lighting.

[0010] Our invention also considers the accumulative errors on the reading process and proposes some techniques to regularly minus the accumulative errors.

[0011] In a first aspect of our invention, a method is provided for detecting cycle completion of a character set running continuously in predetermined sequence through a display area, comprising the steps of:

- (i) capturing an initial image of said display area;
- (ii) storing said initial image as reference image;
- (iii) capturing subsequent images of said display area as characters of the character set run continuously therethrough;

(iv) comparing said subsequent images captured against said reference image until a substantially identical match is found, thus indicating the completion of a cycle of the character set.

5 [0012] Preferably, step (iv) includes correlating said subsequent images against said reference image and tracking the correlation coefficients of said subsequent images until the highest value approaching or equals to 1.0 is achieved. More preferably, the correlating and tracking steps employs autocorrelation method. Most preferably, the correlation coefficients are
10 tracked as a plot of graph to establish peaks, including the highest global peak indicating completion of the cycle of the character set.

[0013] In a second aspect of our invention, the detection of cycle completion of a character set is used in a display positional notation system to
15 indicate an increment to a next position of said positional notation system. The character set may include the base-10 numerical set, particularly wherein the positional notation system comprises a plurality of numerical digits. Thus, upon the completion of a last digit, an image capture of the second last digit may be actuated.

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[0014] In another aspect, the character appearing in the second last digit display prior to actuating image capture is noted, and upon actuation of image capture and successful capture of image, the next character in the character set is assigned to said captured image. Preferably, at every subsequent

completion of the character set cycle, each of the subsequent characters appearing in the second last digit display is captured and assigned to each respective subsequent characters in the character set until all the characters of the character set are thus assigned.

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[0015] The completely assigned character set images are preferably used as reference for character recognition of third last and preceding digits display. Preferably still, the character appearing in the third last digit display is also noted and the correct recognition of the next character in said third last digit display is taken as confirmation of the accuracy of the set of images captured and assigned in respect of the character set.

[0016] Our method may be embodied in recognizing or reading a numerical digit display of a meter, counter, register, measurement device and the like including a watt-hour meter, water supply meter and other utility meters.

[0017] In yet another aspect, our aforesaid methods may be embodied in an apparatus which may include optical image capture device, memory device, and programmable logic device adapted to carry out said methods. This includes having the apparatus adapted to fit onto an existing meter and read its display.

[0018] The apparatus may further including transmitter adapted to receive signals from aforesaid devices representing reading of the meter display and transmitting said signals to a receiving station. The aforementioned devices

may be integrally provided in our apparatus as an integrated circuit. In such compact design, such apparatus may be adapted to fit onto an existing utility meter to enable remote reading of the meter's display in a system incorporating such meters adapted with the aforesaid apparatuses networked to transmit the
5 readings to a central receiver or base.

LIST OF ACCOMPANYING DRAWINGS

10 [0019] Our invention may be better understood with reference to the following drawings for a specific application of our method, i.e. by way of an example of a electric meter, and should not, therefore, be interpreted as being limited to this particular application. The figures are collectively referred to in the Detailed Description that follows.

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[0020] FIGURE 1 illustrates a simplified view of a digit display of a typical utility meter; and

[0021] FIGURE 2 shows a simplified flow diagram of the algorithm
20 according to our invention.

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENT

[0022] FIGURE 1 shows a typical digit display of an analog utility meter (10). Shown here is a 6-digit display wherein the last digit (1) represents the decimal digit which is usually a continuous and fastest moving digit. As this last digit (1) typically appears as a continuous transition of numbers in a cycle as driven by consumption, e.g. torque driven motor in an electric meter (in contrast with discrete number displays of the other digits which are ratchet-driven a notch upon completion of a cycle of the later digit.

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[0023] In FIG. 1, the utility meter's 6-digit display shows a reading slightly passed "00049.4" wherein the last, i.e. decimal, digit (1) shows a transition from "4" to "5". Our method also works for meters that count down but assuming that the display in FIG. 1 is a count up display, the display shows that the figure "00049.4" is moving upwardly to "00049.5".

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[0024] As shown in FIGURE 2, as part of the startup of our algorithm, the user is required at step (22) to note this initial reading down in our algorithm, including the transitional decimal reading of between 0.4 to 0.5. For ease of reference, the last digit (1) is called the decimal digit, the second last digit (2) is called the "ones" digit and the respective preceding digits, the "tens" (3), "hundreds" (4), "thousands" and "ten thousands" digits respectively.

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[0025] Under ordinary circumstances, when the decimal digit runs from ".5"

to ".9" and back to ".0", the "ones" digit position initially showing "9" will advance to "0" thus causing the "tens" digit initially showing "4" to advance to "5" thus displaying a new reading of "00050.0". For the purpose of our method, however, we need not wait for the precise moment of transition of the decimal
5 digit from ".9" to ".0" to define the advancement of the "ones" digit by one value or unit. In fact, we do not even need to define the precise value of the decimal which in this reading example is a transition value between "0.4" and "0.5".

[0026] Our method merely requires that, when this initial decimal image (i.e.
10 between "4" and "5") is displayed again, it is assumed that the decimal cycle has been completed and the singles or ones digit would have advanced by one number or character. Since our initial reading is "49" with the tens digit being "4" and ones digit being "9", our algorithm will assume that it has advance one number, thus advancing the ones digit from "9" to "0" while the tens digit from
15 "4" to "5", giving a new reading of "50".

[0027] Apart from the user being required to provide input in the form of initial reading (22) in order to implement our invention, the user is also required to define a field of image to be captured and recognised. In this regard, the
20 user is required to draw, for example, a rectangle (12) that covers the digit display of the meter so that our OCR algorithm may focus on the delimited field.

[0028] Upon the definition of the field for image capture and recognition, our method will seek to locate each of the digits displayed by detecting their

respective digit windows or boxes using digital image processing techniques for feature extraction such as edge detection method and/or Hough transform method. Based on the initial reading input by the user, our algorithm will know how many separate windows to apportioned the rectangle (12) into. This is
5 represented as step (25). In this example, the rectangle (12) will be automatically segmented (25) into six windows (1, 2, 3, 4, 5 and 6) and, as an additional step to using edge detection and Hough transform, using grey level projection along the horizontal edge of the bounding box for each of the digit displays forming the meter's digit display. The algorithm first performs edge
10 detection to find strong edges inside the detection field (10). Then Hough transform is applied on the edge image to find two longest straight lines which correspond to the two horizontal edges of the electric meter. Thereafter, the edge image is projected along the horizontal edge. The peaks of the projection histogram will correspond to the vertical boundaries of each of the digit.

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[0029] Our method is able to train itself on the fly to get all the characters used in the cycle of the digit display – in this example, to get the images of all the 10 numbers as they appear in this utility meter (10). In other words, there is no need to pre-train our OCR algorithm with the particular font or font size of the digits used
20 in the meter (10). Instead, our algorithm will acquire the images of the digits as they appear in the digit display of the meter (10). The reference image acquisition or templates for each of the numerals is explained in the following.

[0030] The image of the last or decimal digit (1) is first saved in step (23) as a reference image marking a point in the cycle of the digit display regardless of its value, which in our present example, shows a transition between 4 and 5 (i.e. a value of between 0.4 and 0.5).

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[0031] In the next step (24) a new images of the display (12) are grabbed and the sub-images of the last digit (1) will be correlated in step (26) with the saved reference image. The correlation value will first drop from a global peak since the image of the last digit will slowly change to the next digit 5 and
 10 transitions between 5 and 6 and so on. Upon the decimal or last digit (1) reaching 0 the second or last digit (2) will increase by one but our algorithm need not recognise this increment. Instead, it will continue with correlating (26) the sub-images correlation until the correlation value climbs to another global peak.

15 [0032] Upon hitting another global peak, it means that the last digit display (1) is displaying the transition between ".4" and ".5" again and has therefore gone through a complete cycle and that the second last digit, i.e. the ones digit, would have advanced to the next number. Since at the user calibration step (22) the second last digit is known and which image may thus be captured as
 20 number "n". In our present example, the second last digit "9" would have thus advanced to "0". The new number's image may thus be recognised and saved as a template for the number next in the series or character set (i.e. $n+1$, wherein n is the initial number for the second last digit noted by the user during calibration step (22).

[0033] The process may thus be repeated when the last digit or decimal digit image correlation reaches the next global peak to signal that $n+2$ number is now displayed in the second last digit and the OCR may now capture the image of this next number (i.e. "1" in our example). In this manner the templates for each of the numbers or character set may be obtained on-the-fly by our invention and saved (27) as the meter is allowed to run. In our example, the templates for all the 10 numbers of the second last digit may thus be obtained after the last or decimal digit has completed 9 cycles.

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[0034] After the templates for all the ten digits have been stored, the template set (28) is now ready for reading recognition mode. In particular, the digit displays for the ones or second last digit (2), tens or third last digit (3), hundreds or fourth last digit (4), thousands or fifth last digit (5), ten thousands or sixth last digit (6) (and so forth in larger digit displays) may now be recognised accurately. This is applicable as these digits for all positions normally have the same font and size. At this stage, many OCR methods or other alternatives may be used given that the digit template set has been built up. In our present invention, the thrust is to use correlation-based approach to enable OCR to be performed, i.e. providing a method by which we may correlate the digit templates with actual image to find the one with best correlation score.

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[0035] While the digits (2) to (6) typically have the same font and size, this may not be the case for the last or decimal digit (1) as explained above, i.e.

it may be smaller font size or different font type, have calibration lines, etc. If the font type and size of the decimal digit (1) is the same as the rest, the template set (28) compiled may be used to recognise the sub-image of the last or decimal digit as well although this decimal digit was initially used only as an indication of cycle completion as described above. For each new image, the sub-image of the last digit may be compared with the templates of the current and next readings. For example, if the current reading of the last digit is transitional 4 – 5, the sub-image of the last digit will be correlated with the templates of “4” and “5”. When the correlation value with template “5” is much greater than that of template “4”, the total reading may be increased by 0.1. Using this approach, the reading accuracy can achieve the level of 0.1.

[0036] Occasionally, some errors may arise, for example, sometimes the correlation result may show that the last digit has increased by 1, but actually it has not. Or, sometimes, the correlation result shows the last digit has not changed, but actually it has increased by 1. Both cases will make the overall meter reading inaccurate. Although these errors are not significant, but it occurs repeatedly, the errors may accumulate to become significant and may make the reading result unacceptable.

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[0037] To solve this problem, we use the saved reference image of the last digit to continuously correlate with the actual image of the last digit to detect whether it has gone through a complete cycle. Since this correlation is more reliable, we can simply update the meter reading result after a complete round

is detected and the reading does not match with the prediction. Using the same example illustrated in FIGURE 1 and assume that the current reading is 00049.4. At the moment that we detect the last digit has gone through a complete round, the reading shall be 00050.4. But our template matching
5 result might be 00050.3 due to some matching errors. In this case, we can update the reading to be 00050.4 directly.

[0038] Although the foregoing description of our invention has been illustrated in respect of 10 base number system, it is obvious to a skilled person
10 that our invention is also applicable to a display of positional notation system employing any character set or code page which sequence has been predetermined so that a cycle of all the characters displayed may be completed. It may also be obvious to a skilled person that certain portions of our algorithm may be reused for confirmation of the correctness of our OCR reading,
15 accumulative readings, etc.

[0039] It is further to be understood that although the specific embodiment described above is in respect of a utility meter display, our algorithm may be implemented for any display of devices having any number of positional
20 notation digits. Such devices may include analog or digital meters, counters, measuring devices, and the like. These are to be considered as falling within the scope and letter of the following claims.

CLAIMS

We claim:

- 5 1. A method for detecting cycle completion of a character set running continuously in predetermined sequence through a display area, comprising the steps of:
 - (i) capturing an initial image of a character of the character set of said display area;
 - 10 (ii) storing said initial image as a reference image;
 - (iii) capturing a subsequent image of a second character of the character set running continuously therethrough;
 - (iv) correlating the subsequent image against said reference image whereby a correlation value is obtained;
 - 15 (v) repeating steps (i) to (iv) until the correlation value reaches a peak indicating completion of the cycle of the character set,wherein an image of the next last character set is captured and assigned as a template.
- 20 2. A method according to claim 1, wherein steps (i) to (v) are repeated until the templates of all the characters of the next last character set are assigned and stored.
3. A method according to Claim 1 wherein steps (iv) and (v) includes
25 tracking the correlation values of said subsequent images until the highest

value approaching or equals to 1.0 is achieved.

4. A method according to Claim 3 wherein the correlating and tracking steps employs autocorrelation method.

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5. A method according to Claim 2 wherein the correlation values are tracked as a plot of graph to establish peaks, including the highest global peak indicating completion of the cycle of the character set.

10 6. A method according to any one of Claims 1 – 4 wherein the detection of cycle completion of a character set is used in a display positional notation system to indicate an increment to a next position of said positional notation system.

15 7. A method according to Claim 6 wherein the character set is the base-10 numerical set.

8. A method according to Claim 7 wherein the positional notation system comprises a plurality of numerical digits.

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9. A method according to Claim 6 used in a positional notation display to detect the completion of a last digit and upon such completion, actuate an image capture of the second last digit.

10. A method according to Claim 9 wherein the character appearing in the second last digit display prior to actuating image capture is noted, and upon actuation of image capture and successful capture of image, the next character in the character set is assigned to said captured image.

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11. A method according to Claim 10 wherein at every subsequent completion of the character set cycle, each of the subsequent characters appearing in the second last digit display is captured and assigned to each respective subsequent characters in the character set until all the characters of
10 the character set are thus assigned.

12. A method according to Claim 11 wherein the completely assigned character set images are used as reference for character recognition of third last and preceding digits display.

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13. A method according to Claim 12 wherein the character appearing in the third last digit display is also noted and the correct recognition of the next character in said third last digit display is taken as confirmation of the accuracy of the set of images captured and assigned in respect of the character set.

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14. A method according to any one of Claims 6 – 13 embodied in a numerical digit display of a meter, counter, register, measurement device and the like including a watt-hour meter, water supply meter and other utility meters.

15. An apparatus implementing any one of the methods of Claims 1 – 14 including optical image capture device, memory device, and programmable logic device adapted to carry out said methods.
- 5 16. An apparatus according to Claim 15 adapted to fit onto an existing meter and read its display.
17. An apparatus according to Claim 15 further including transmitter adapted to receive signals from aforesaid devices representing reading of the meter
10 display and transmitting said signals to a receiving station.
18. An apparatus according to any one of Claims 15 – 17 wherein the devices are integrally provided as an integrated circuit.
- 15 19. A utility meter adapted with an apparatus according to any one of Claims 15 – 18.
20. A utility meter remote reading system comprising a plurality of utility meters each affixed with an apparatus according to any one of Claims 15 – 18
20 and a receiver for receiving the meter readings as transmitted by the apparatus.