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(54) **Method and device for controlling banknotes**

(57) A method of controlling banknotes (2) having a first and a second print (O, T) executed at different stages, the method providing for acquiring the luminance values (Vb) of the pixels (P) of an image of a banknote (2); comparing each luminance value (Vb) with a respective luminance value acceptance range (I); and emitting a reject signal in the event at least one of the luminance values (Vb) is outside the respective acceptance range (I); a respective acceptance range (I) being determined statistically for each pixel (P) as a function of the luminance values (Vb) of the pixel (P) acquired from the banknotes (2).

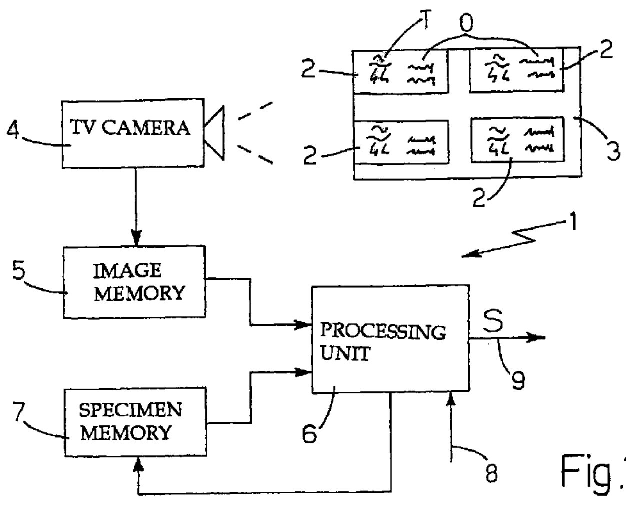

Fig.1

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Description

[0001] The present invention relates to a method of controlling banknotes.

[0002] As is known, banknotes are made from a sheet of such a size as to contain several finished banknotes, and which comprises watermarked regions and/or regions including metal bands, and is fed along a given path along which it undergoes various printing steps, each involving a different printing technique.

[0003] The most common printing steps are offset printing, i.e. of images normally representing a coloured background; intaglio or copperplate printing, i.e. of famous faces and numbers representing the value of the banknote; and silk-screen printing, i.e. of the serial number. Offset printing is performed on both faces with no alignment with the edge of the sheet, which therefore cannot be used as a reference for the coordinates of the offset printed details.

[0004] Intaglio printing is performed at high pressure using a plate, and deforms the paper slightly so that the plate is inclined with respect to the offset print, and the intaglio print itself possibly misaligned with respect to the offset print rollers. Intaglio printing is performed on one or both faces of the sheet, and may comprise a number of successive prints, each of which may be misaligned with respect to the offset or other intaglio prints. Misalignment of the various successive prints may take the form of translation along the x and/or y axis, or rotation.

[0005] Once offset and intaglio printed, the sheet is quality controlled and cut into separate banknotes. The quality control process consists in assigning a pass or reject signal to each banknote, and only the passed banknotes are silk-screen printed with serial numbers.

[0006] Quality control is frequently performed manually by a checker, who ensures the offset and intaglio prints do not deviate too far from an ideal value, and checks for coloring errors, i.e. over- or underinked regions, blurring or other defects.

[0007] Alternatively, quality control may also be performed automatically using a television camera, which assigns each pixel a characteristic luminance value of a given banknote surface associated with the pixel, and compares these values with a respective acceptance range. If at least one of the detected values is outside the respective acceptance range, the banknote is rejected. Automatic control is complicated by numerous factors, foremost of which is determining acceptance ranges enabling accurate control of both coloring and misalignment, which in turn is complicated by the luminance of each pixel depending on various factors, such as the printed region partly occupying the surface corresponding to the pixel, and the type of ink and paper used. The problem is further compounded by misalignments of up to a millimeter between the intaglio and offset prints being considered acceptable, and by effective colour control requiring the use of television cameras of such definition that each pixel corresponds to a banknote surface portion of 0.125 X 0.125 square millimeters. Misalignment to the above extent, in relation to the size of said surface portion, therefore means the luminance value of each pixel may vary within a very wide range, due to the surface portion corresponding to the pixel possibly being fully inked or having no ink at all, particularly when the surface portion in question is located at the edge of a figure. On the other hand, wide acceptance ranges would fail to provide for effective control by possibly passing banknotes which should be rejected.

[0008] It is an object of the present invention to provide a control method enabling reliable automatic control of banknotes.

[0009] According to the present invention, there is provided a method of controlling banknotes comprising a first and a second print executed at different stages; the method comprising the steps of acquiring the luminance values of the pixels of an image of a banknote; comparing each said luminance value with a respective acceptance range of values relative to each pixel; and emitting a reject signal in the event at least one of said luminance values is outside the respective acceptance range; said method being characterized in that each said acceptance range of each respective pixel is determined as a function of the respective luminance values of said pixel acquired from the banknotes.

[0010] The method according to the present invention is particularly advantageous by determining, for each pixel, a respective range which, in some cases, particularly for pixels close to the edges of the figures or numbers, may be relatively wide, and, in the case of pixels some distance from the edges of the figures or numbers, may be relatively narrow; and by the control device determining the relatively wide and relatively narrow ranges statistically from the banknotes themselves.

[0011] The present invention also relates to a device for controlling banknotes.

[0012] According to the present invention, there is provided a device for controlling banknotes comprising a first and a second print executed at different stages; the device being characterized by comprising a television camera for acquiring the luminance values of the pixels of an image of a banknote; a specimen memory for storing luminance acceptance ranges of respective pixels; and a processing unit for comparing each said luminance value with the respective acceptance range relative to each pixel; said unit emitting a reject signal in the event at least one of said luminance values is outside the respective acceptance range, and calculating said acceptance range of each pixel as a function of the luminance values of said pixel acquired from the banknotes.

[0013] A non-limiting embodiment of the present invention will be described by way of example with reference to the accompanying drawings, in which:

Figure 1 shows a block diagram of a device for implementing the method according to the present invention;

Figure 2 shows a flow chart of a first operating mode of the Figure 1 device;

Figure 3 shows a flow chart of a second operating mode of the Figure 1 device;

Figures 4a and 4b show two portions of two different banknotes corresponding to the same pixel.

[0014] Number 1 in Figure 1 indicates a device for controlling banknotes 2 printed on a sheet 3. Control device 1 comprises a television camera 4 for picking up one banknote 2 at a time and generating a discrete, digitized grey-tone television signal which is transmitted to an image memory 5. Memory 5 stores the images of banknotes 2 in the form of respective matrixes of dots or so-called pixels P, each of which is assigned a value Vb related to the grey level, i.e. luminance, of pixel P. In other words, image memory 5 acquires, for each banknote 2, a succession of luminance values Vb relative to each pixel P of banknote 2. As shown clearly in Figures 4a and 4b, each pixel P corresponds to a 0.125 mm square surface portion of banknote 2, and value Vb of each pixel P represents a mean value of the luminance of the respective surface portion. Figure 4a shows a banknote portion corresponding to a given pixel P1 of the image of a banknote 2, and which, as can be seen, is occupied partly by an intaglio print T and partly by an offset print O; and, similarly, Figure 4b shows a portion corresponding to the same pixel P1 of the image of another banknote 2. That is, the two portions relate to pixels with the same coordinates in two images of respective banknotes 2. As can be seen, on account of the deviations involved, the parts of the two portions occupied by the intaglio and offset prints T and O differ widely, thus resulting in a considerable variation in the luminance value Vb relative to pixel P1 of two separate, both acceptable, banknotes 2.

[0015] Memory 5 is connected to a processing unit 6, which comprises an image processing section, i.e. an image processor, and a logic section, and which provides for processing and comparing the image of banknote 2 with acceptance ranges I. For which purpose, processing unit 6 is connected to a specimen memory 7 which supplies the elements by which to determine ranges I. Processing unit 6 also comprises an input 8 by which processing unit 6 receives external data or commands, and an output 9 by which processing unit 6 supplies a signal indicating acceptance or rejection of the controlled banknote 2. Unit 6 also supplies specimen memory 7 with the luminance values Vb of the accepted banknotes 2, which are entered to form part of the specimens.

[0016] Banknotes 2 are produced using a known method comprising the steps of advancing sheet 3, which is sized to contain a number of banknotes 2; printing, in one printing step, the graphic portion of the image representing the coloured background of each banknote 2, and which is commonly referred to as the offset print O; printing, in one printing step, the portion representing the dark image and value figures of each banknote 2, and which is commonly referred to as the intaglio or copperplate print T; controlling the quality of the printing; printing the serial numbers on the accepted banknotes 2; and cutting sheet 3 to separate each banknote 2 in said number of banknotes 2 from the others.

[0017] In actual use, the device comprises a so-called control operating mode, whereby, as described previously, the acquired luminance values Vb are compared with respective acceptance ranges I; and an automatic learning mode, whereby banknotes 2 are not controlled, and device 1 acquires the luminance values Vb of pixels P of banknotes 2 solely to determine respective acceptance ranges I.

[0018] In control mode, as shown in Figures 1 and 2, in a block 10, camera 4 stores the images in memory 5 in the form of values Vb relative to respective pixels P; and memory 5 transfers values Vb to a block 11 where the acquired value Vb of each pixel P is compared with a respective acceptance range I ranging between values Vb1 and Vb2 supplied to processing unit 6 by specimen memory 7 corresponding to block 12 in Figure 2. In block 13, if at least one of values Vb is outside range I, a reject signal is emitted via output 9 of unit 6, and banknote 2 is rejected as shown in block 14. Conversely, if values Vb are all within respective ranges I, an accept signal is emitted via output 9, and banknote 2 is accepted as shown in block 15. The new values Vb transmitted to specimen memory 7 are used, together with values Vb already in specimen memory 7, to determine a new mean value Vbm and new values Vb1 and Vb2 defining the limits of respective ranges I. Once defined in block 16, the new ranges I are transferred to block 12.

[0019] In other words, the luminance values Vb of the controlled and accepted banknotes 2 serve to define the mean value Vbm of each range I and the widths of ranges I, and, alongside the control mode, device 1 continues to acquire information by which to determine ranges I.

[0020] As shown in the Figure 3 diagram, automatic learning mode provides for determining ranges I of each pixel P relative to banknotes 2 which have never been controlled by device 1 and for which no historical data exists by which to calculate mean values Vbm and respective limit values Vb1 and Vb2. That is, in a block 17, a television camera acquires the images, i.e. the values Vb of each pixel P in N number of banknotes 2 which have never been controlled in any way, either manually or automatically; values Vb are stored in image memory 5; a reject signal is emitted for all N number of banknotes 2 (block 18); and, at the same time, mean values Vbm and values Vbmin and Vbmax defining a reference range Is for each pixel P are calculated as a function of the acquired values Vb (block 19).

With reference to block 20, values Vbmax and Vbmin define for each pixel P the limits of ranges Is, which serve to subsequently define ranges I according to the equation $I = Is * k$, where k is an experimentally defined coefficient of less than 1. The range I so determined is placed exactly about respective mean value Vbm according to the limit equation:

$$Vb1 = Vbm - 1/2$$

and

$$Vb2 = Vbm + 1/2$$

[0021] Once defined, ranges I are transferred together with values Vb1 and Vb2 to specimen memory 7 (block 21). At this point, device 1 is set to control mode, and the N banknotes 2 used to determine ranges Is are controlled by device 1 to determine whether values Vb are within respective ranges I, and are rejected if the above condition is not met.

[0022] In control mode, device 1 acquires values Vb of all the accepted banknotes 2 from specimen memory 7 to determine, at each control cycle, a mean value Vbm of values Vb of all the accepted banknotes 2, and so recalculate limits Vb1 and Vb2 according to the above equation. Specimen memory 7 retains the mean values Vbm of each cycle to determine the existence of a systematic drift in value Vbm possibly caused by defects involving the printing devices (known and not shown). When the difference between the first and last mean value Vbm exceeds a given value A determined experimentally, processing unit 6 emits an emergency signal via output 9 to call for a check of the printing device (known and not shown) and for a manual check of banknotes 2 to determine the extent of the drift.

[0023] In a variation not shown, device 1 comprises a learning mode whereby memory 5 acquires values Vb of N previously, e.g. manually, controlled banknotes 2 to determine mean values Vbm, maximum values Vbmax and minimum values Vbmin of respective pixels P. In this case, in view of the fact that banknotes 2 are all accepted banknotes, maximum and minimum values Vbmax and Vbmin correspond to respective values Vb1 and Vb2, and the range between maximum and minimum values Vbmax and Vbmin corresponds to range I.

[0024] In a further variation, values Vb1 and Vb2 are determined as follows:

$$Vb1 = Vbm - sigma$$

$$Vb2 = Vbm + sigma$$

where sigma is the mean square deviation of luminance values Vb of accepted banknotes 2.

[0025] In a further variation not shown, device 1 comprises a purely control mode whereby values Vb of the accepted banknotes 2 are not acquired, and ranges I are determined solely as a function of the first N banknotes 2.

Claims

1. A method of controlling banknotes comprising a first and a second print (O, T) executed at different stages; the method comprising the steps of acquiring the luminance values (Vb) of the pixels (P) of an image of a banknote (2); comparing each said luminance value (Vb) with a respective acceptance range (I) of values relative to each pixel (P); and emitting a reject signal in the event at least one of said luminance values (Vb) is outside the respective acceptance range (I); said method being characterized in that each said acceptance range (I) of each respective pixel (P) is determined as a function of the respective luminance values (Vb) of said pixel (P) acquired from the banknotes (2).

2. A method as claimed in Claim 1, characterized by acquiring and memorizing the luminance values (Vb) of a number (N) of banknotes (2); determining the respective acceptance ranges (I) as a function of said luminance values (Vb); and acquiring further luminance values (Vb) to be checked with reference to said acceptance ranges (I).

3. A method as claimed in Claim 2, characterized by calculating, for each pixel (P) and on the basis of the respective luminance values (Vb), a mean luminance value (Vbm) of said number of banknotes, and by determining a maximum value (Vbmax) and a minimum value (Vbmin), and a reference range (Is) extending between said maximum value (Vbmax) and said minimum value (Vbmin).

4. A method as claimed in Claim 3, characterized in that said acceptance ranges (I) equal the respective reference ranges (Is) multiplied by a coefficient (k) determined experimentally.

5. A method as claimed in any one of Claims 1 to 4, characterized in that said acceptance range (I) is modified as a function of controlled and accepted banknotes (2).

6. A method as claimed in Claim 5, characterized by calculating the mean luminance value (Vbm) of each pixel (P) and the limit values (Vb1, Vb2) of said acceptance range (I) on the basis of the luminance values (Vb) of controlled banknotes (2).

7. A method as claimed in Claim 6, characterized in that said limit values (Vb1, Vb2) are respectively equal to the mean luminance value (Vbm) plus half the acceptance range (I), and to the mean luminance value (Vbm) minus half the acceptance

range (I).

8. A method as claimed in Claim 6, characterized by calculating the mean square deviation (sigma) on the basis of the luminance values (Vb) of controlled banknotes (2); said limit values (Vb1, Vb2) being respectively equal to the mean luminance value (Vbm) minus the mean square deviation (sigma), and to the mean luminance value (Vbm) plus the mean square deviation (sigma).

9. A device for controlling banknotes comprising a first and a second print (O, T) executed at different stages; the device being characterized by comprising a television camera (4) for acquiring the luminance values (Vb) of the pixels (P) of an image of a banknote (2); a specimen memory (7) for storing luminance acceptance ranges of respective pixels (P); and a processing unit (6) for comparing each said luminance value (Vb) with the respective acceptance range (I) relative to each pixel (P); said unit (6) emitting a reject signal in the event at least one of said luminance values (Vb) is outside the respective acceptance range (I), and calculating said acceptance range (I) of each pixel (P) as a function of the luminance values (Vb) of said pixel (P) acquired from the banknotes (2).

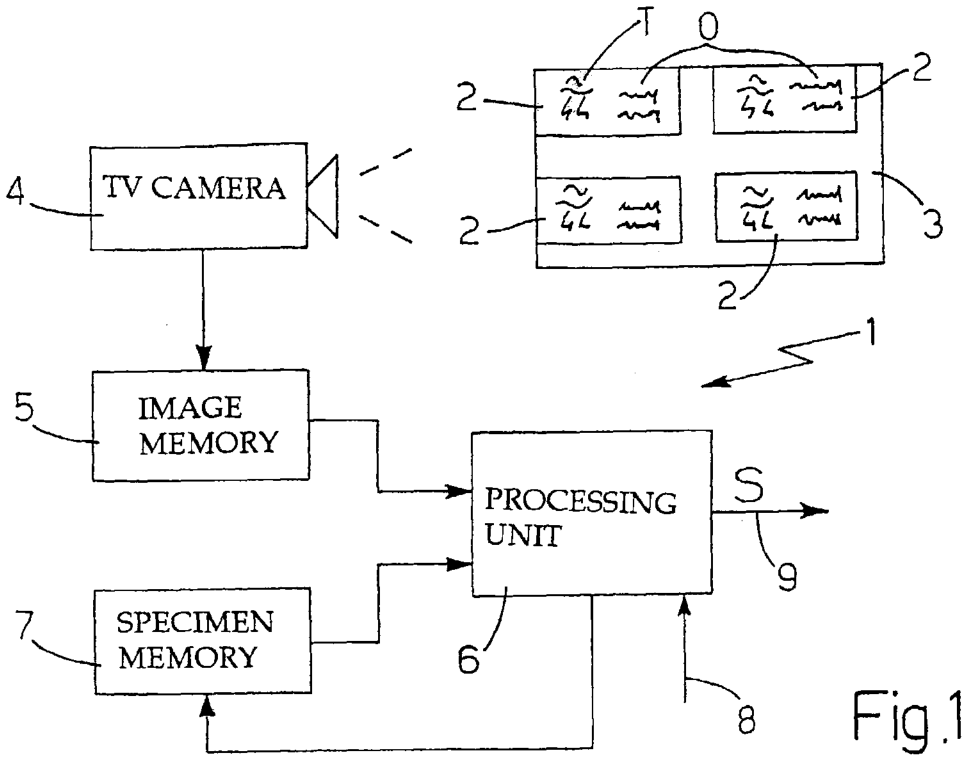

T
0
2
2
2
2
3
4
TV CAMERA
1
5
IMAGE MEMORY
PROCESSING UNIT
S
9
7
SPECIMEN MEMORY
6
8

Fig.1

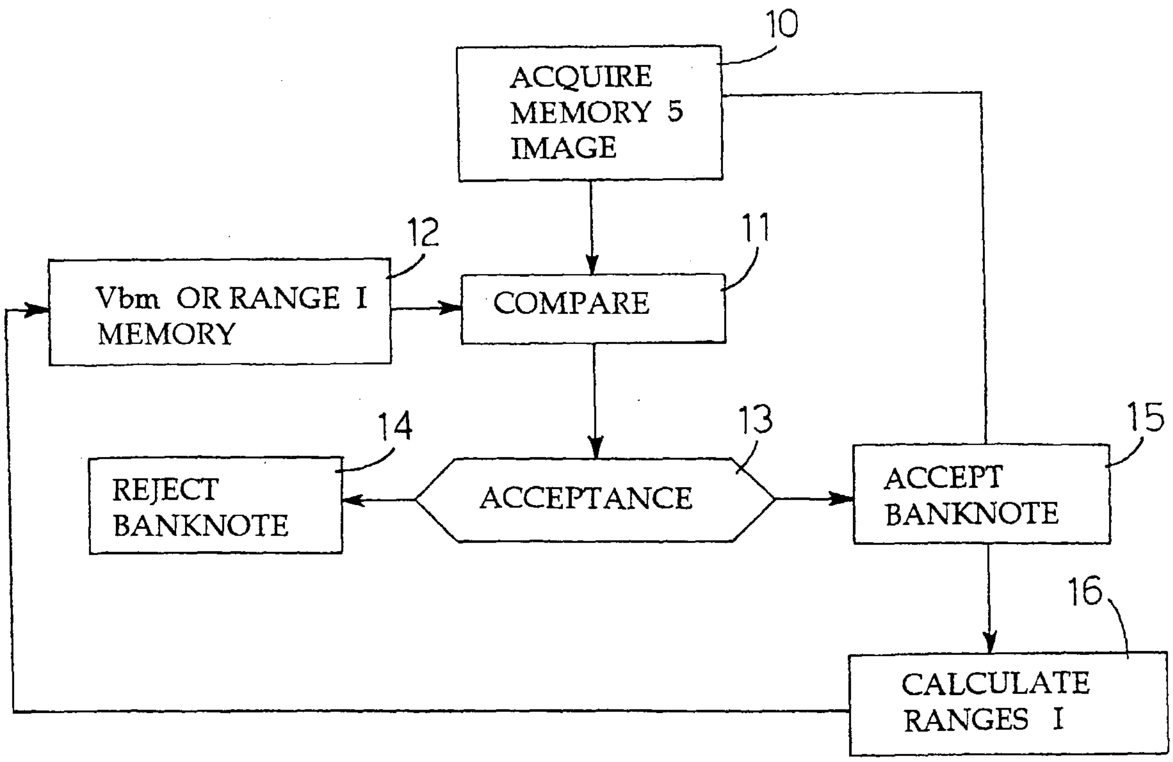

10
ACQUIRE MEMORY 5 IMAGE
12
11
Vbm OR RANGE I MEMORY
COMPARE
14
13
15
REJECT BANKNOTE
ACCEPTANCE
ACCEPT BANKNOTE
16
CALCULATE RANGES I

Fig.2

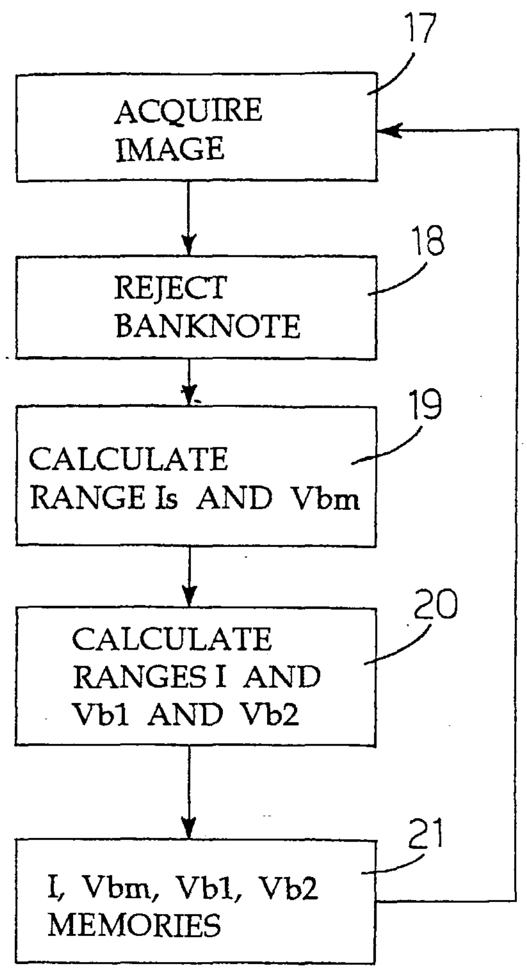
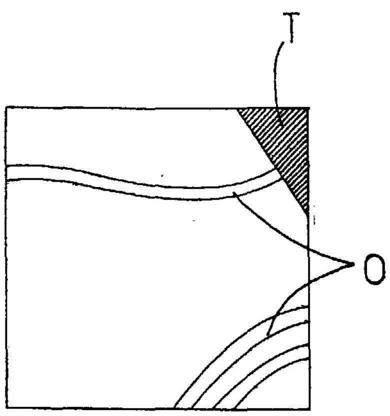


Fig.3



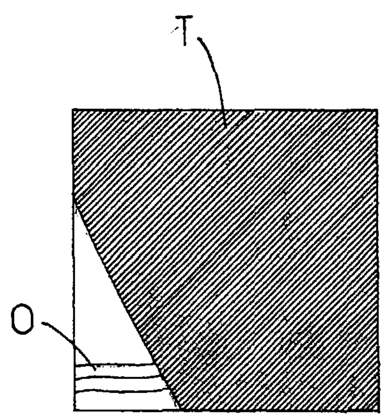


Fig.4a

Fig.4b

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EUROPEAN SEARCH REPORT

Application Number
EP 99 11 4520

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	16 December 1999	Kirsten, K

CATEGORY OF CITED DOCUMENTS

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