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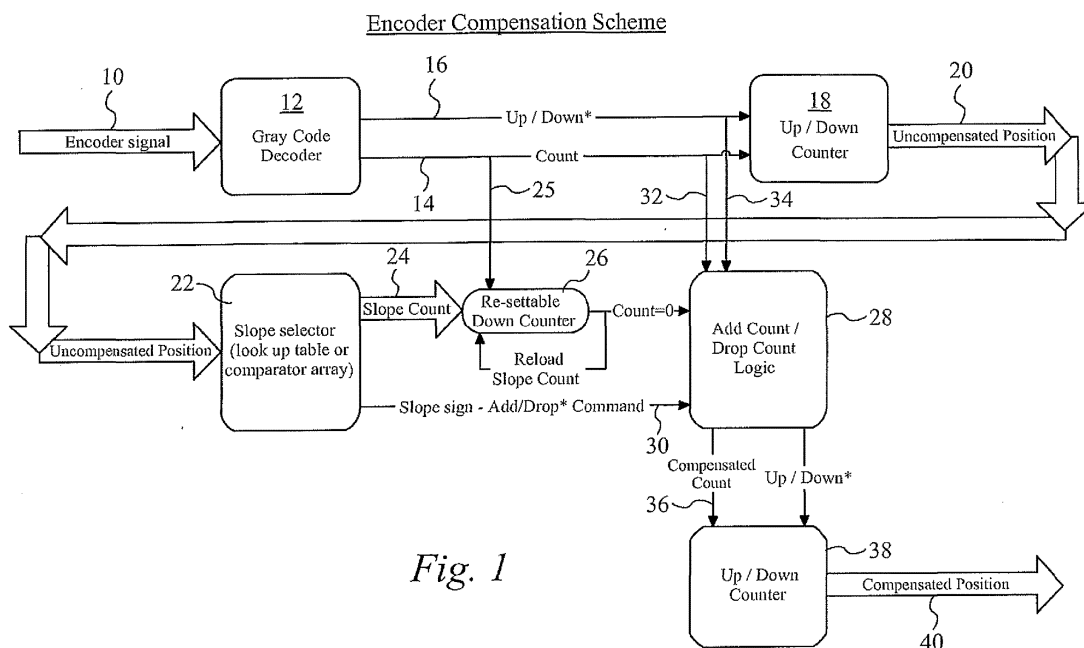
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GB 2037464 A EP 0990531 A1
EP 0925928 A2 JP 2007261158 A
JP 2006015542 A JP 2004061322 A
US 5988784 A US 5576744 A
US 5308974 A US 20070285467 A1
US 20050078134 A1 US 20040090478 A1
US 20040027583 A1 US 20030206304 A1
US 20020196298 A1

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(54) Title of the Invention: **Print gap compensation**
Abstract Title: **Print gap compensation**

(57) In an ink jet printer, where there is relative movement between a print carriage and a print table in order to print on to a substrate mounted on the table, the gradient of the print table at each position of the print carriage is used to produce a compensated position of the print carriage, and printing data is sent to the print head according to the compensated position instead of the actual position. This delays or advances the release of ink, to compensate for the difference in the time taken for the ink to reach a substrate mounted on the print table when the print gap between print heads and print table is not constant. Varying the timing of the release of ink from the print head is based on a local measure of the print gap.



Encoder Compensation Scheme

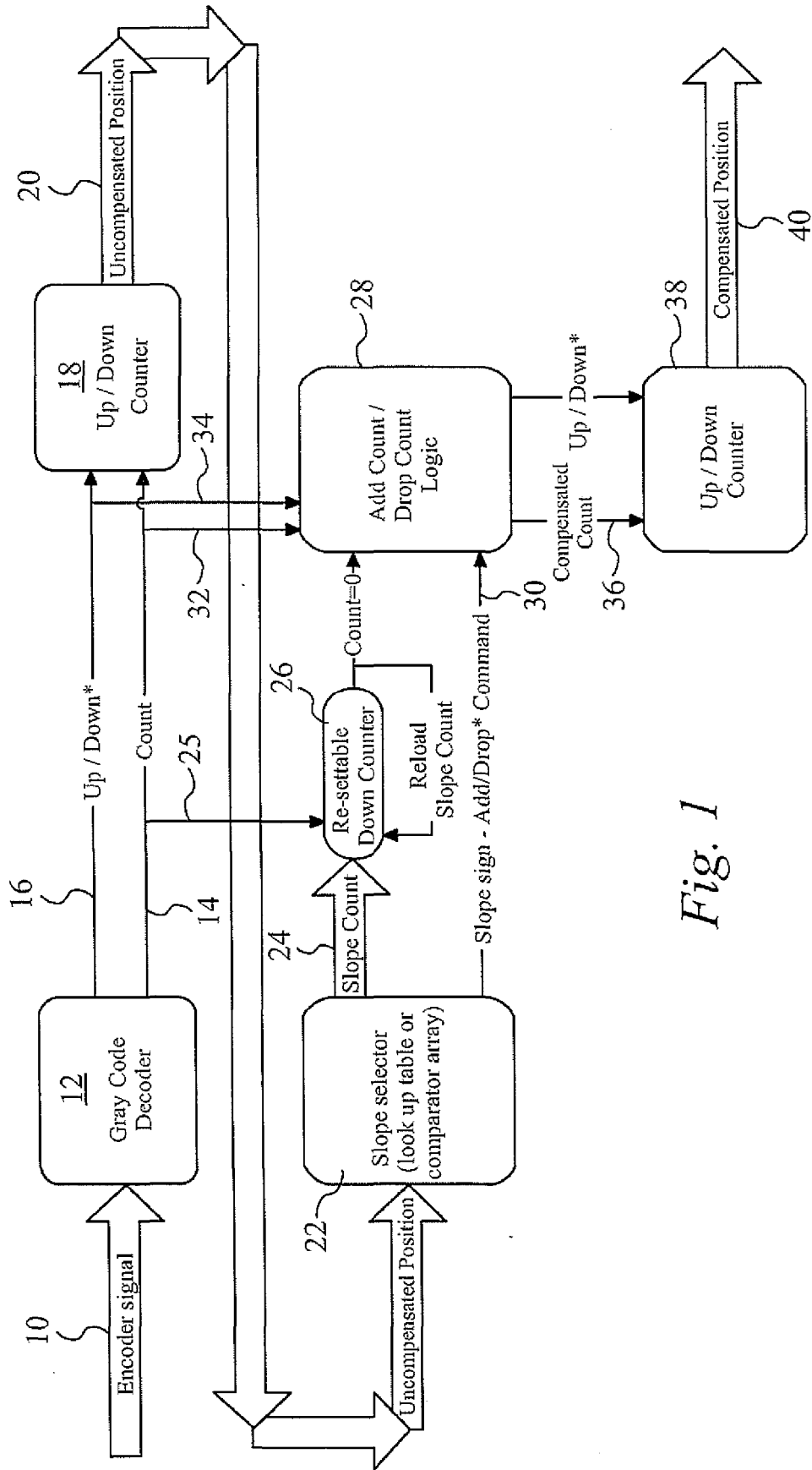
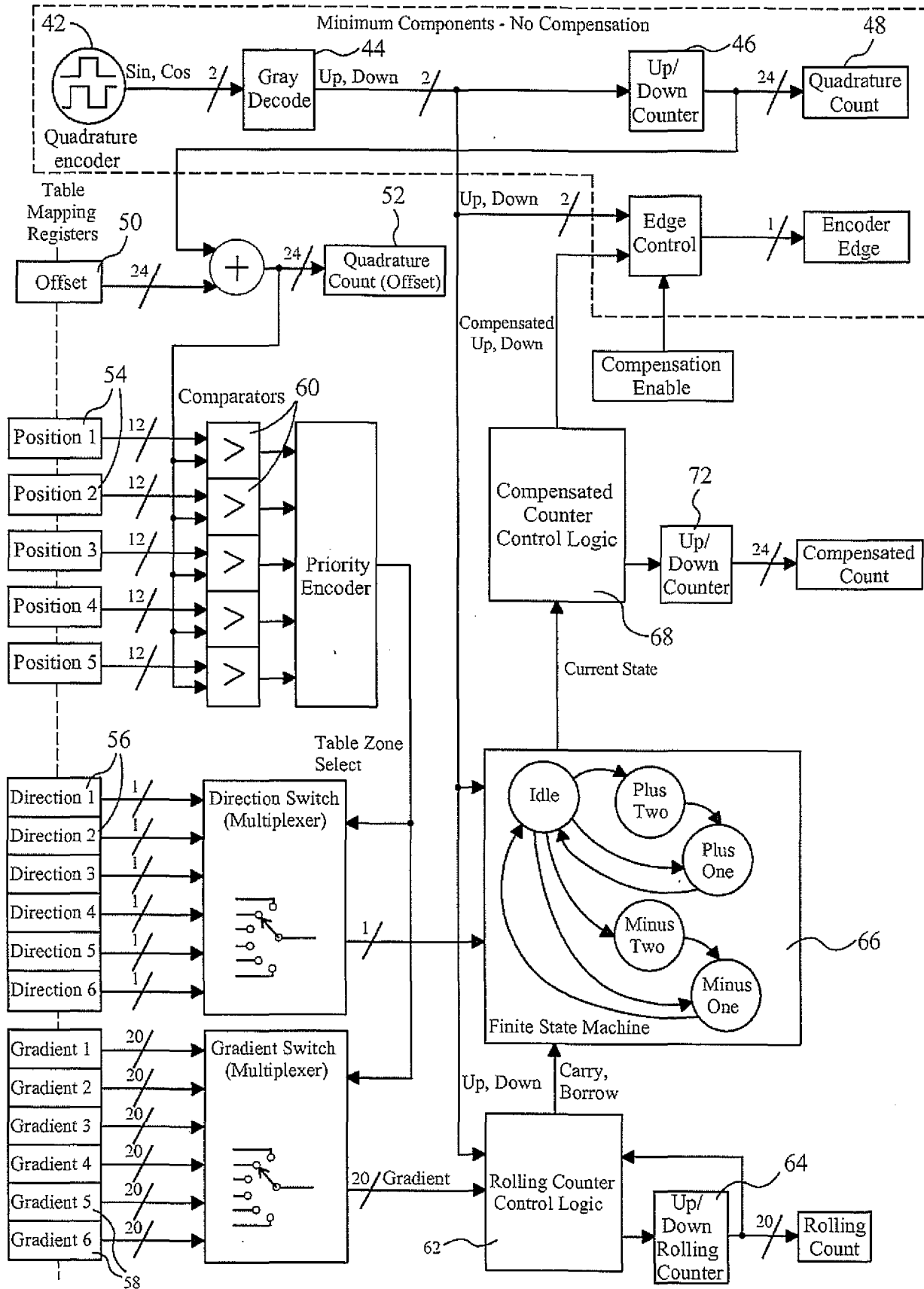


Fig. 1

Fig. 2 Encoder Compensation Scheme



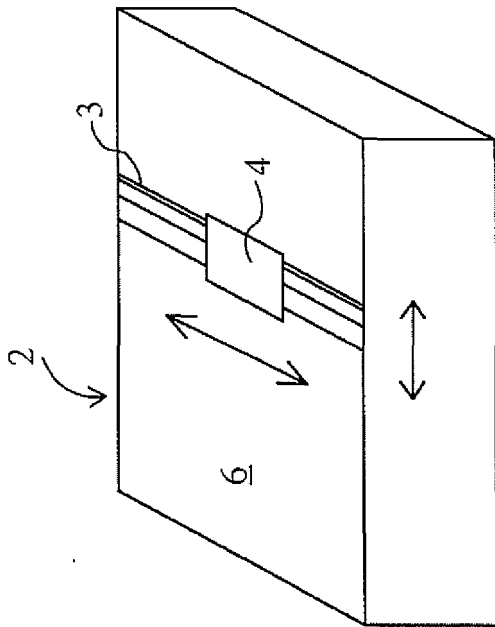


Fig. 3

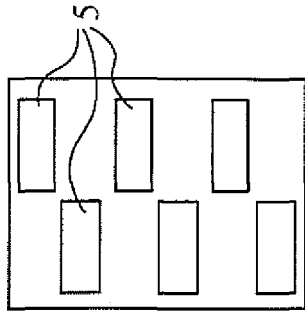


Fig. 4

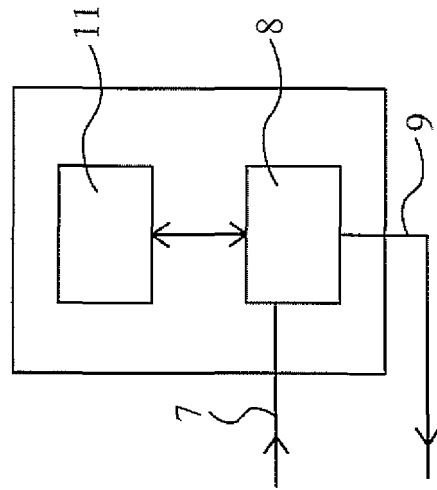


Fig. 5

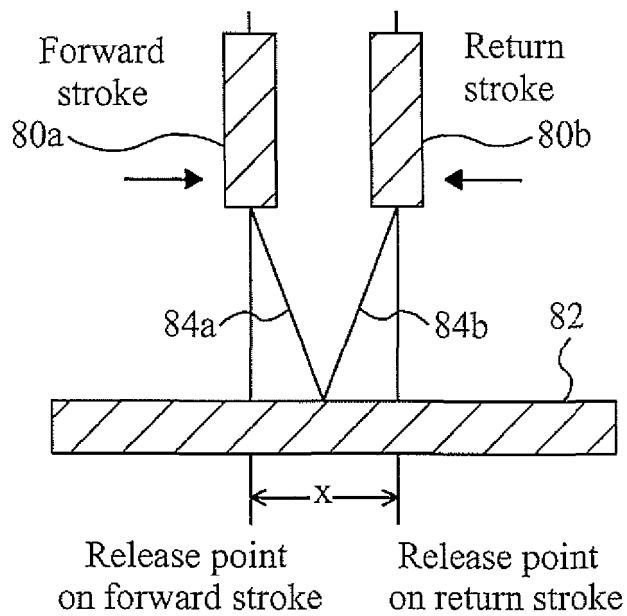


Fig. 6

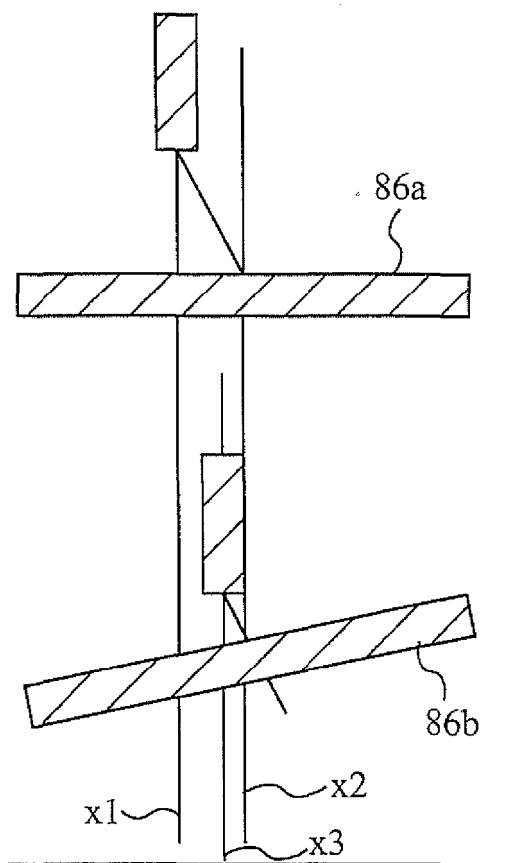


Fig. 7

Print Gap Compensation

This invention relates principally to compensating for variations in the print gap in an ink jet printer, although some novel techniques disclosed herein have wider applicability.

Ink jet printers produce an image on a substrate by 'firing' ink droplets from nozzles provided on a print head as the print head traverses the substrate. Commonly the substrate is supported on a surface such as a print table, and the print head is mounted on a carriage which moves back and forth across the width of the substrate printing a line or swathe of ink with each pass to build up the required printed image. Movement in an orthogonal direction may be by moving a carrier of the print carriage. Alternatively the print head is caused to traverse the substrate by moving the print table (or other assembly which supports the medium such as rollers) under the print heads, or a combination of movement of the heads and table; references herein to a print head traversing a substrate are intended to encompass any arrangement which produces relative movement, whether by movement of the carriage or table or both.

In such printers, variations in the gap between the print head and the substrate, known as the 'print gap', can cause defects in the printing. In practice, the print gap will not be constant due to factors such as variations in the substrate thickness, distortions in the substrate support, in the case of a table typically due to thermal effects and inaccuracies in the print head transport system. A particular issue the invention deals with is that a print table, even if manufactured and adjusted within close tolerances, tends to deform as the temperature changes during use, but the invention can address problems with other support mechanisms.

When printing with inkjet, the position in which the ink droplet lands on the substrate, relative to the point of release from the print head, is affected by the droplet velocity, the speed of the print heads relative to the substrate and the gap between print heads and substrate. Therefore if the print gap is not constant, then the time taken for the ink to reach the substrate from a nozzle of a print head will vary over the area of the table. Where the print head is moving across the substrate, and thus the ink droplet is travelling along an inclined trajectory, this variation can result in small errors in the position in which each droplet of ink deposited. This is particularly important in bi-directional printing, where variations give double images or "fuzzy" text. However, even for uni-directional printing the placement accuracy may be

important, for example in non-graphics inkjet applications, such as materials deposition in flat panel displays.

5 This is also a particular problem in large printers, where the print table has a large area compared to the print gap, distortions due to thermal expansion may be significant, and the print head and substrate move relative to each other at a high speed. Whilst previous methods have attempted to adjust the table surface, small variations in the flatness of the table and/or distortions occurring during use may be difficult to avoid.

10

Furthermore, there may be a requirement to print an image onto a substrate which is not flat; for example when printing an image onto a textured surface or a shaped article, such as a wood-grain pattern onto a moulded door. If a simple image is printed onto such substrates, small discontinuities or distortions of the image may occur.

15

The present invention aims to provide a method of printing which compensates for such variations in the print gap.

20 According to a first aspect, the present invention provides a method of printing with an ink jet printer comprising, as the print head traverses the print area, varying the timing of the release of ink from the print head based on a local measure of the print gap.

25 Therefore the timing of the release point may be adjusted throughout the print, so that the droplets of ink land close to the required position even though the gap between the print heads and the substrate is changing.

Whilst the absolute size of the print gap could be used to determine the timing of ink release, conveniently the timing is varied based on the rate of change of the local measure of the print gap along the printing direction. Thus the ink droplets may be released from the nozzles of the print head either earlier or later depending upon whether the print gap is increasing or decreasing, such that they reach a substrate mounted on the print table at substantially the same spacing as if the table were flat.

35 Therefore the print quality may be improved.

Commonly, the print head traverses the print area in a printing direction sequentially along a plurality of printing lines. Preferably the method comprises obtaining a measure of the print head position in at least the printing direction using an encoder arranged to generate a sequence of pulses as the print head traverses the print area, wherein varying the timing of ink release is effected by processing the encoder pulses.

This method has the advantage of requiring minimal adjustment to existing electronic systems in the printer, which can receive and use the processed encoder pulses in the usual manner, since the timing of the pulses has been changed to compensate for changes in the print gap. Furthermore, there is no need to carry out complex processing of the image data.

Conveniently the method comprises using the local measures of the print gap to obtain a timing compensation value representative of the rate of change of the print gap. For example the compensation value may have a size dependent upon the gradient or slope of the print gap, and a sign representative of the direction of the slope. This value can be applied to the encoder pulse to add or delete pulses depending upon the sign of the compensation value at a rate dependent upon the size of the compensation value. This provides a simple method of processing the encoder pulses.

Preferably the encoder pulses have a finer granularity than the print resolution such that alteration of the encoder pulses may be used to effect very small changes in the position of an ink droplet. Thus an encoder pulse may correspond to less than half or less than a quarter of the width of the ink droplet spacing, and preferably about a tenth of the droplet spacing. For example, if the print resolution is 1200dpi, giving an ink droplet spacing of about 20 microns, the encoder may produce about twenty pulses to each droplet spacing, giving a pulse for every 1 micron across the print direction. In contrast, whilst compensation could be carried out by distorting the data representing the image to be printed by moving the pixels within it, this technique would be limited to a resolution of one print grid pixel. If it is desired to use correction, the image may be over-sampled, for example the image may be upsampled to a virtual print resolution of say 2400dpi and a correction applied to the upsampled image to give half pixel correction; this requires more processing for each image but on the other hand this can be achieved in software if the existing hardware can support the resolution.

Preferably the method comprises obtaining a compensation value by measuring the print gap and comparing the measurement with a measurement of the print gap at an adjacent position along the printing direction. The print gap may be measured by measuring the height of the print table or substrate, or the distance between the print table or substrate and the print carriage or print head.

The method preferably comprises storing a series of timing compensation values for various positions over the print area. Interpolation may be used to provide intermediate values. The compensation values may be derived by scanning the print table or the substrate to be printed, or from printing and analysing (by examination using a scanner or by direct visual inspection) a calibration image or test pattern, or a combination.

The scan may comprise measuring the print gap at a plurality of positions over the area of the print table or substrate, to produce a 'map' of the topography. The gap data may then be simplified to provide an approximation of the rate of change of the print gap by approximating the gap along the printing direction as a plurality of regions of constant slope for each line of printing, using known methods. For example, five slope regions across the width of the table have been found to give sufficient accuracy for typical variations in a printer table having a width in the region of about two metres.

Alternatively, the measurements of the print gap may take place in real time as printing is taking place (or near-real-time, for example on a scanning pass before a printing pass, or on a prior printing pass), for example using a camera or other sensor mounted on the print carriage. If measurement takes place during printing, the method has the additional advantage that it may be used to compensate for any distortion of the print table which may take place during printing.

In some applications, the print gap height variation may be a known function of position and/or time, for example where the print table is caused to distort due to thermal expansion which takes place as the printer heats up during use. Thus the local measure may be calculated or derived from a parameter or parameters which characterise the distortion, for example from a measure of the print gap at a particular reference position, and/or from a measure of temperature or operation time or energy flux into the print table.

Thus the compensation value at a particular position may be obtained from stored data using a simple look up table, or by using a comparator where the data comprises compensation regions. Where the compensation value indicates that the print gap is decreasing, the release of ink is delayed, and vice versa. This may be achieved by using the compensation value to provide a compensated position for providing print data to the print head. Thus print data is provided to the print head for releasing ink as if it were in a position either slightly ahead of or slightly behind the actual position. This is a simple and effective way of compensating for the difference in the print gap.

Where the print head traverses back and forth across the print area, the encoder processing as described above may result in the image length being shorter in terms of encoder pulses in one direction than the other, since a given slope in the print gap will result in pulses being added in one direction and deleted in the other. To facilitate processing, the encoder pulse sequence preferably is arranged to provide an edge count having a small positive value at the start of the image (rather than zero), preferably exceeding the largest count to be subtracted. This makes it straightforward in hardware or software to add or delete counts in order that the image data remain in correct registration, without counters needing to cycle through zero.

A second aspect of the invention further provides a method of calibrating a print table comprising deriving compensation data by scanning the print table to measure variations in the height of the table, and calculating compensation values based on the variations, such as the rate of change of the table height in the printing direction.

It will be appreciated that the invention could be applicable to other situations where a work head projects onto a work surface at non-normal incidence and the gap between the two varies; for example, a laser beam writing obliquely onto a non-flat surface, or the inspection of a non-flat surface with an inclined microscope. Furthermore modelling of the table height variation may be applicable to other applications where the shape of a work surface or the gap between a work surface and a work head varies.

Thus the invention also provides, according to a third aspect, a method of providing a working measure of the topography of a work surface comprising storing at least first and second representations of the topography corresponding

respectively to first and second conditions, and obtaining the values of at least one parameter associated with each of the first and second conditions, and providing the working measure based on a working value of the parameter and the stored representations of the topography.

5

It has been found that, surprisingly, although imperfections and deformities in a work surface, particularly one which is intended to be flat and which is typically constrained at several points, may be complex and difficult to predict in absolute terms, and may vary between measurements, variation over typical operating ranges may be usefully characterised by one or only a few parameters, typically a measure of temperature or of deflection at one point, or a relatively small number of points, on the substrate table.

10

In this way local values of a work surface height or deflection may be obtained simply without the need for multiple direct measurements when the topography is changing with conditions such as temperature variation. The stored representations may comprise detailed height maps of stored measurements or may comprise simplified models, for example fitting measured values of height values to one or more curves or series of straight lines.

15

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The working value of the parameter may be a measured value such as a measure of temperature, a derived value such as a measure of energy flux, or an input value such as a measure of operation time.

25

The representations of topography may be obtained by taking measurements of the work surface at one or more reference locations, and modelling the topography based on interpolation between the measurements or an approximation using stored coefficients of characteristic curves. Such coefficients may be obtained by calculating the best fit between the measurements. It has for example been found that thermal expansion of a print table tends to give a constant radius of curvature relative to the table centre.

30

Interpolation may also be used between the stored representations of the topography for different values of the parameter, which interpolation may be

linear or non-linear or based on an intermediate measure. The topography may also be modelled as a stored function of the parameter.

5 The value of the at least one parameter may be obtained for different regions of the work surface, and interpolation may be carried out between the regions. Thus for example if one region of the work surface is at a higher temperature than another, a more accurate topography may be obtained.

10 The working measure of topography may be used to provide the local measure of print gap in an ink jet printer according to the first aspect of the invention.

In a fourth aspect, the invention provides an inkjet printer comprising:
a print carriage mounting at least one print head, and a print table, the print carriage and the print table arranged to be movable with respect to each other in
15 a printing direction along a plurality of print lines;
an encoder for providing a position signal indicating the position of the print carriage at least in the printing direction; and
a compensation system arranged to process the encoder signal based on a local measure of the print gap.

20 The compensation system may comprise a data store for storing a model of the variation of print gap topography across print area with variation of at least one parameter, apparatus arranged to obtain the value of the or each parameter, and a processor arranged to compensate for variation of the print gap based on the
25 stored model and the value of the parameter.

The processor may compensate for variations in the print gap using a working measure obtained by the method according to the third aspect of the invention.

30 The invention also provides, in a fifth aspect, software and/or firmware for an ink jet printer comprising a data store for storing timing compensation values based on the local position of the printer carriage, and apparatus for processing an encoder pulse of the printer carriage using the timing compensation values.

According to sixth aspect the invention provides a method of processing a work surface using a work head traversing the surface, comprising varying the timing of the processing dependant upon a local measure of the gap between the surface and the work head.

5

The invention also provides an ink jet printer comprising a compensation system for carrying out the method of the invention.

10 In order that the invention may be more readily understood, reference will now be made, by way of example, to the accompanying drawings, in which:

Figure 1 is a block diagram showing a method according to one embodiment of the invention;

15 Figure 2 is a block diagram of logic suitable for implementing the method shown in Figure 1;

Figure 3 is a schematic perspective view of a printer suitable for use in accordance with the method of the invention;

20

Figure 4 is a schematic underneath view of the print heads of Figure 3;

Figure 5 is a block diagram showing a compensation module for implementing the method according to the invention; and

25

Figures 6 and 7 are diagrammatical cross-sections of a print head and substrate.

Referring to Figures 3 and 4, it is well known for an ink jet printer 2 to comprise an encoder 3 producing a sequence of pulses for monitoring the position of the printer carriage 4 which mounts the print heads 5 with respect to the print table 6 or substrate which is mounted on the table. In this example, the printer carriage moves over the print table, but in other arrangements the print head or heads may be stationary whilst the print table is moved. Reference to the print heads traversing the print table is intended to include either arrangement or a combination of both.

35

The encoder position is used to send print data to the print head according to the image required to be printed. The release of the ink droplets as the print heads lay

down a pass of print is controlled by electronic hardware which is fed a signal from the linear encoder reporting the position of the print heads relative to a reference position. Alternatively a stepper motor may be used to drive the print carriage, in which case the stepper motor pulse train may be used to indicate position, and
5 reference hereinafter to an encoder pulse includes such a drive pulse or signal derived from such a drive pulse.

Referring now to Figure 1, in use of the method of the invention, an encoder signal
10 representing the printer carriage position as it traverses the print area, which may be in Gray code, is passed to a decoder 12 to produce a count signal 14 and a direction signal 16. The count signal represents the linear position of the print carriage along the printing direction, and the direction signal indicates which way the carriage is travelling across the substrate, which will be referred to as either 'up' or 'down'. These signals pass to a counter 18, which outputs an uncompensated
15 position 20, which according to the prior art is then used to control the output of data to the print heads for printing the required image.

According to the invention, this uncompensated position is adjusted by processing
20 the encoder pulses depending on the variation of the print gap or print table height, to give a compensated position for use in controlling the print heads. Referring to Figure 5, the encoder pulse 7 is processed by a compensation module 8 to produce an adjusted or compensated encoder pulse 9. The compensation module obtains a compensation value from a data store 11 depending upon the encoder position, and applies the compensation value to alter the encoder pulse.

25 For example, referring to Figure 1, the uncompensated position is passed to a slope selector 22 to determine a slope count 24. The slope count is representative of the rate of the change or gradient of the print gap at that position; for example if the slope is steep then the slope count is small, and vice versa. The slope count may be
30 derived from the height run-out of the print table in the printing direction, for example in metres per metre, which is scaled by the ratio of the ink droplet velocity to the print speed (the speed of movement of the print carriage), which ratio represents the angle of the droplet trajectory relative to the table, to give the slippage factor. The reciprocal of this gives the slope count for each slope region, which serves as a
35 compensation value and can be loaded in to the control system.

Where the print table has been mapped in advance of printing, the slope selector can use a simple look up table to find the slope count at the relevant position along the printing line, for example using the higher significance bits of the uncompensated position. Conveniently, the measured variation in print gap or table height can be modelled for example to give a number of approximated slope regions with end points (eg five regions) along each print line, using a known method. One such method minimises the squared difference between a piece-wise linear fit and the actual profile. In other words, the height of the table or substrate is measured as a function of position, and a set of piecewise linear approximations to the surface is fitted to the measurements by standard regression techniques. Thus when printing a particular print stripe, interpolation is used to create a set of coefficients appropriate to the stripe position and the data fed to the control electronics.

The slope selector can use a comparator array to select a slope count by determining in which slope region the uncompensated position lies. The slope count 24 is loaded into a slope counter 26, which counts down triggered by an input 25 from the encoder count signal 14. Each time the slope counter 26 reaches zero, the slope count 24 is reloaded into the slope counter. Also when the slope counter reaches zero, a count pulse is either deleted or added to the uncompensated position count. Thus for example when the slope is shallow, the slope count is high, and the down counter counts down to zero infrequently, so few counts are added or removed. A small slope count leads to a greater rate of addition or deletion of counts.

Whether a count is deleted or added is dependent upon whether the slope is positive or negative, and the encoder count direction, which together show whether the print gap is increasing or decreasing. This is determined by an add/drop logic circuit 28 which receives an input 30 from the slope selector 22 comprising an add or drop command, depending on the sign of the slope, and inputs 32 and 34 representing the encoder count and whether the count is up or down.

Thus a compensated count 36 is produced to drive an up/down counter 38 which generates the compensated position 40. The compensated position is used in place of the uncompensated position to control the output of data to the print heads.

For example, where the slope is such that the print gap is increasing as the print carriage moves along, counts are added so that the print head releases the ink droplets slightly earlier. The further the print heads move, the more counts are

added, as the larger the gap gets, and the earlier the ink is released. This compensates for the increasing time of flight of the ink droplets to reach the substrate as the print gap increases. In other words, the compensated position count is increasing more quickly than the real position. When the print head moves back over the same slope in the opposite direction, the gap is getting smaller, counts are dropped, and the ink release is delayed in a similar fashion.

Referring to Figure 7 for example, it can be seen that an ink droplet released when the encoder reads a value X1 lands at position X2 when the substrate 86a is flat. However when the substrate 86b is sloping such that the print gap is getting smaller, the ink droplet which is to land at position X2 needs to be released when the print carriage is further along at actual position X3 because of the shorter flight time of the ink droplet. Thus the compensated encoder counts up less than one count per actual encoder count so that the ink release trigger point X1 is only reached when the print head has reached the actual position X3.

When printing bi-directionally, conventionally a fixed offset between the release positions in the forward and backward (or up and down) print directions is applied for all positions on the image so that the droplets printed are in registration. Figure 6 shows the droplet trajectory 84a when the print carriage 80a is moving in the forward direction, and the trajectory 84b when the carriage 80b is moving in the backward direction. It can be seen that the release points for droplets to land in the same position on the substrate 82 are offset by a distance x.

Where printing is bi-directional across a sloping surface as described above, it will be appreciated that in the compensated position encoder counts will be added when printing in one direction and removed when printing in the other direction. Thus the image is shorter in terms of unadjusted encoder counts in one direction than in the other. In order that the print data for each direction remain in correct registration, the start position of the out and back print strokes can be adjusted to account for the difference in apparent length. This may be done by adding or deleting an appropriate edge offset value to the encoder position at the beginning of each print stroke.

Thus using knowledge of the nominal print gap, print speed and droplet velocity the required coefficients for the encoder count modification, and the offsets between forward and backward strokes are generated and used to produce the appropriate compensated encoder count.

Referring now to the circuit of Figure 2, a quadrature encoder 42 sends a signal to a gray decoder 44. The output from the decoder 44 passes to an up/down counter 46 to give a quadrature count 48. Table mapping registers provide an edge offset 50 to give an offset quadrature count 52. The mapping registers also provide print gap data in the form of table position values 54 with associated gradients 58 for each direction 56. An array of comparators 60 is used to select the applicable table zone to provide the applicable gradient or compensation value to the rolling counter control logic 62. The rolling control logic 62 provides a carry/borrow signal to a finite state machine 66, which provides the current state to compensated counter control logic 68. The control logic 68 provides a compensated count 70 via a further up/down counter 72.

The encoder compensation as described above necessarily is applied to all of the print heads regardless of their position on the print carriage, since there is a single encoder position for the print carriage. Since the print carriage has a finite width, the print heads 5 may be mounted in different positions across the width of the carriage 4, orthogonal to the print direction 15, known as the nozzle direction 13 (see Figures 3 and 4). It is possible to carry out a further correction adjustment for each print head depending upon their relative positions on the print cartridge. This adjustment can be carried out by applying a correction offset to each print head dependent upon where each print head is located, and the print gap variation in the nozzle direction. In a similar manner to that described above, the variation in the print gap can be scaled by the velocity ratio of the ink droplets to print speed to give offset values for each print head. Thus print heads which are in a position where the print table is lower may fire earlier in order that the ink droplets arrive in the correct position, and vice versa.

In some applications, such as in large format printers, the print head array may span substantially the entire width of the printable area. The encoder position compensation necessarily affects all print heads across the width. Thus a correction factor needs to be applied dependent upon the print head position in both the print direction and the nozzle direction.

Furthermore in such printers the large table area and the significant power output from the curing lamps can lead to significant thermal expansion and ensuing distortion. It has been found that table height variation due to such factors can in some circumstances be modelled as a separable function of the print

direction, position, x , and the nozzle direction position, y . That is, the height variation can be modelled as $h(x,y) = f(x) + g(y)$, where f and g are both functions of different position variables. In such circumstances, the corrections for print gap variations in the print direction can be made by the insertion or deletion of encoder pulses and the

5 corrections for print gap variations in the nozzle direction can be made independently by adjusting the timing of the printhead firing based upon its position in the nozzle direction. This technique can be conveniently applied when the print head array covers the entire, or a substantial part of, the printable width.

10 On machines having a printhead array which is short in the nozzle direction in comparison with the printable width of the substrate (as measured in the nozzle direction), the print gap need not be modelled as a separable function as interpolation can be used for each print swath in order to represent the print gap as $h(x,y)$.

15 It has been surprisingly found that conveniently, in certain printer arrangements, height variation due to thermal expansion can be reasonably well approximated by assuming a constant radius of curvature. Thus a representation of the table topography may be obtained by measuring the height of the table at a reference

20 location. This is found to be convenient for some particular physical arrangements but, for the avoidance of doubt, the invention is much more generally applicable to printing arrangements where this an approximation does not usefully apply. More generally, in a given arrangement, there may be another approximation that gives a useful simplification and the invention generally provides adjusting timing based on a

25 model of variation. The model may be mathematical or approximated by a lookup table or a combination, with whatever precision is required for the application; it has been appreciated that even correction based on a crude simple model which has not been calibrated to a specific printer may in practice be significantly better than an uncompensated prior art arrangement.

30 Thus under certain circumstances, a single parameter (such as the height measured at a particular point on the table) can be used to calibrate an underlying model of the table distortion and thus table height at any given position. For example, in such a case, if we measure the table height H , at position X,Y , and we assume a model of

35 the distortion of the form $h = A*(x^2 + y^2)$ or a similar approximation, then the parameter A is determined and we can estimate h at any point at the time the height measurement was taken.

The height variation may also vary over time, for example due to the table heating up with use. If the distortion varies sufficiently slowly with time, it may not be necessary to measure the height directly – a simple adjustment of the scaling parameter ("A" in the above formula) by the machine operator may be sufficient to achieve adequate compensation. In other words the form $h(x,y,t) = A(t) * (x^2 + y^2)$ may be suitable for some applications. In use, the measure of deflection at a point, or some other measure or combination of measures such as the temperature difference across the table, or energy flux measure or time of use or a measure of strain at a point may be used to derive an operating parameter. Values of $A(t)$ can for example be obtained by taking measurements and interpolating therebetween.

Where a handling mechanism other than a table is used, other corrections may be used. For example, where a substrate is passed between rollers, a measure, or model or approximation of varying amounts of sag between the rollers or support points may be applied in addition to measure of variation along the axis of the rollers, and again the print gap may be a separable function of x and y position.

In an embodiment ink jet printer, where there is relative movement between a print carriage and a print table to print on to a substrate mounted on the table, the gradient of the print table at each position of the print carriage is used to produce a compensated position of the print carriage, and printing data is sent to the print head according to the compensated position instead of the actual position. This delays or advances the release of ink, to compensate for the difference in the time taken for the ink to reach a substrate mounted on the print table when the print gap between print heads and print table is not constant.

It will be appreciated that the techniques disclosed herein may be used together in an ink jet printer, or separately, and in other applications and all features disclosed herein may be provided independently unless otherwise expressly stated.

Claims

5 1. A method of printing with an ink jet printer comprising, as the print head traverses the print area, varying the timing of the release of ink from the print head based on a local measure of the print gap.

2. A method as claimed in claim 1, comprising varying the timing based on the rate of change of the local measure of the print gap along the printing direction.

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3. A method as claimed in claim 1 or 2, comprising using the local measures of the print gap to derive a timing compensation value.

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4. A method as claimed in claim 3, comprising storing a series of timing compensation values for a plurality of positions over the print area.

5. A method as claimed in claim 4, comprising using interpolation to provide intermediate timing compensation values between stored timing compensation values.

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6. A method as claimed in any preceding claim, comprising obtaining a measure of the print head position in at least the printing direction using an encoder or stepper motor arranged to provide a sequence of encoder pulses as the print head traverses the print area, and varying the timing of ink release by processing
25 the encoder pulses.

7. A method as claimed in claim 6, comprising further varying the timing of the release of ink from each of a plurality of print heads mounted on the print carriage depending upon the position of the print head relative to the print carriage.

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8. A method as claimed in claim 6 or 7 when dependent on claim 3, 4 or 5, comprising adding or deleting pulses of the sequence.

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9. A method as claimed in claim 8, in which each pulse represents a distance which is not more than a quarter of the ink droplet spacing.

10. A method as claimed in any preceding claim, comprising obtaining a local
measure of the print gap by measuring the height of the print table or substrate,
or the distance between the print table or substrate and the print carriage or print
5 head.

11. A method as claimed in any one of claims 1 to 9, comprising obtaining the
local measures of the print gap by scanning the print table or substrate, and/or by
printing a calibration image.
10

12. A method as claimed in any one of claims 1 to 9, comprising obtaining the
local measure of the print gap using a measuring device mounted on the print
carriage.

13. A method as claimed in any one of claims 1 to 9, comprising calculating the
local measure of the print gap as a function of the position of the print head.
15

14. A method as claimed in claim 13, comprising storing a model of print gap
variation across the print area for each of a plurality of values of at least one
parameter, and providing the local measure of the print gap dependent upon an
20 input or measured value of the or each parameter.

15. A method of calibrating a print table or substrate comprising deriving
compensation data by scanning the print table or substrate to measure variations
25 in the height of the table, and calculating compensation values for use in
adjusting the timing of release of ink for printing on the table or substrate.

16. A method of providing a working measure of the topography of a work surface
comprising storing at least a first and second representations of the topography
30 corresponding respectively to first and second conditions, and obtaining the
values of at least one parameter associated with each of the first and second
conditions, and providing the working measure based on a working value of the
parameter and the stored representations of the topography.

17. A method as claimed in claim 16, in which the working value of the parameter is a measured or derived value or an input value.

18. A method as claimed in claim 16 or 17, in which the parameter is a measure
5 of temperature, energy flux, or operation time.

19. A method as claimed in claim 16, 17 or 18, in which each representation of topography is obtained by taking measurements of the work surface at one or more reference locations.

10

20. A method as claimed in claim 19, in which each representation of the topography is based on an approximation of topography using the measure(s) at the reference location(s) and stored coefficients of characteristic curves.

15 21. A method as claimed in claim 20, in which the coefficients are obtained by taking measurements at a plurality of locations and calculating the best fit between the measurements.

22. A method as claimed in any one of claims 16 to 21, in which interpolation is
20 used between the stored representations of the topography based on the working value of the parameter to provide the working measure of the topography.

23. A method as claimed in claim 22, in which the interpolation is linear or non-linear based on an intermediate measure.

25

24. A method as claimed in claim 22, in which the topography is modelled as a stored function of the parameter.

25. A method as claimed in any one of claims 16 to 24, comprising obtaining the
30 value of the at least one parameter corresponding to at least first and second regions of the work surface respectively, and interpolating between the regions,

26. An inkjet printer comprising:

a print carriage mounting at least one print head, and a print table, the print carriage and the print table arranged to be relatively movable in a printing direction along a plurality of print lines

- 5 an encoder for providing a position signal indicating the position of the print carriage at least in the printing direction; and
a compensation system arranged to process the encoder signal based on a local measure of the print gap.

10 27. An ink jet printer as claimed in claim 26, in which the compensation system comprises a data store for storing a model of the variation of print gap across print area with variation of at least one parameter, apparatus arranged to obtain the value of the or each parameter, and a processor arranged to compensate for variation of the print gap based on the stored model and the value of the parameter.

15

28. Apparatus for compensating for print gap variation in an ink jet printer, comprising logic for providing timing compensation values based on the local position of the printer carriage, and apparatus for processing encoder pulses indicating a position of the printer carriage using the timing compensation values.

20

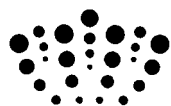
29. Apparatus for compensating for print gap variation in an ink jet printer comprising logic for providing local measures of print gap based on an obtained parameter relating to the printer operational condition, and logic for adjusting the timing of ink release from print heads of the printer based on the local measures.

25

30. An ink jet printer comprising a compensation system arranged to carry out the method as claimed in any one of claims 1 to 25.

30 31. Software and/or firmware for an ink jet printer comprising a data store for storing timing compensation values based on the local position of the printer carriage, and apparatus for processing an encoder pulse of the printer carriage using the timing compensation values

32. A method of processing a work surface using a work head traversing the surface, comprising varying the timing of the processing dependent upon a local measure of the gap between the surface and the work head.



Application No: GB1110107.8

Examiner: Mr Marc Collins

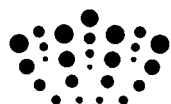
Claims searched: 1-15 and 26-32

Date of search: 7 October 2011

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1, 15, 26, 28, 29, 31 and 32 at least	US 2005/078134 A1 (IGARASHI) See whole document especially abstract and figures 7-8.
X	1, 15, 26, 28, 29, 31 and 32 at least	JP 2007261158 A (NORITSU KOKI CO. LTD.) 11.10.07. See WPI Abstract Accession No. 2007-769727 [72] and figures.
X	1, 15, 26, 28, 29, 31 and 32 at least	EP 0925928 A2 (CANON) See whole document especially abstract and figures.
X	1, 15, 26, 28, 29, 31 and 32 at least	US 2004/090478 A1 (MILLER) See whole document especially abstract and figures.
X	1, 15, 26, 28, 29, 31 and 32 at least	US 2007/285467 A1 (TANAKA et al.) See whole document especially paragraphs [0007]-[0011] and figures 9-10.
X	1, 15, 26, 28, 29, 31 and 32 at least	JP 2006015542 A (SEIKO EPSON CORP.) 19.01.06. See WPI Abstract Accession No. 2005-313467 [32] and figures.
X	1, 15, 26, 28, 29, 31 and 32 at least	US 5576744 A (NIIKURA et al.) See whole document especially abstract and figures.
X	1, 15, 26, 28, 29, 31 and 32 at least	US 2002/196298 A1 (CHENG et al.) See whole document especially abstract, paragraph [0014] and figures.



X	1, 15, 26, 28, 29, 31 and 32 at least	EP 0990531 A1 (HEWLETT-PACKARD CO.) See whole document especially abstract and figures.
X	1, 15, 26, 28, 29, 31 and 32 at least	US 5988784 A (TAKEMURA et al.) See whole document especially abstract and figures.

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^X :

Worldwide search of patent documents classified in the following areas of the IPC

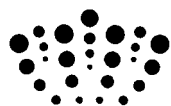
B41J

The following online and other databases have been used in the preparation of this search report

EPODOC, WPI

International Classification:

Subclass	Subgroup	Valid From
B41J	0002/045	01/01/2006
B41J	0029/393	01/01/2006



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Claims searched: 16-25

Date of search: 10 February 2012

Patents Act 1977
Further Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
A	-	JP 2004061322 A (MITUTOYO CORP.) 26.02.04. See EPO abstract and WPI Abstract Accession No. 2004-273760 [26].
A	-	US 5308974 A (ELINGS et al.)
A	-	GB 2037464 A (RANK ORGANISATION LTD)
A	-	US 2004/027583 A1 (DULMAN)
A	-	US 2003/206304 A1 (DAVIS et al.)

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^X :

Worldwide search of patent documents classified in the following areas of the IPC

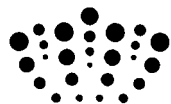
G01B

The following online and other databases have been used in the preparation of this search report

EPODOC, WPI

International Classification:

Subclass	Subgroup	Valid From
B41J	0002/045	01/01/2006



Subclass	Subgroup	Valid From
B41J	0029/393	01/01/2006
G01B	0021/30	01/01/2006