Next Generation Infinity Printer

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ABSTRACT: *A printing system may have unrestricted printing area and no moving parts. The printer is a handheld device which when swiped over the paper to be printed, prints out the required data properly irrespective of the movement of the device. It also hints areas which are yet to be printed.*

Keywords: Printing, Inkjet, Portable, Consumer Appliance

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1. Introduction

Printing of documents is a bridge between the virtual world and the real world. Printing is a very common activity and the two most common types of printing technologies are inkjet and laser printing. Printers are usually bulky compared to the paper they print. This bulk restricts the portability of the printer and increases power consumption. The traditional printing technique also severely restricts the maximum printable dimensions.

Common Inkjet printers utilize an ink cartridge that is moved across the width of the paper to produce the print. On the other hand laser printing usually prints a full page width by toner transfer method. Our device exploits the movement requirement of the inkjet printer to reduce size and weight and increase portability. The technique also removes the printable area restrictions ie prints can be taken on papers of any dimensions.

2. Current Inkjet Printers

2.1 Working

A common desktop inkjet printer works by having two separate motions. The print head carriage, which holds the ink cartridge and the print nozzle, is moved across the whole width of the widest paper size printable. The paper is moved using rollers from one end to the other.

To print, the print head is first moved across the width while the print head prints the required image onto the paper. Once a line is printed, the next rollers turn to move to the paper by one print line width and then the process is repeated.

2.2 Problems and sources

The three major problems that can be easily identified from day to day usage are:

1) **The device is not portable:** Portability is restricted due to the bulk of the device as well as the power consumption. The bulk can be mostly attributed to the print head movement mechanism and the rollers

2) **The device consumes significant power**: The significant part of the power is consumed by the stepper motors used for the carriage and roller movements.

3) **The largest paper that can be printed is restricted:** The print size is dictated by the roller width of the printer which is usually equal to the maximum printable width and to the effective carriage movement (excluding the resting position).

2.3 Solution

All three problems outlined above can be overcome using a single strategy, viz. remove the automatic movement, ie the rollers and the cartridge movement. The rest of this paper describes how this is achieved in the Infinity Printer and the related issues.

3. How to Use

The Infinity Printer relies on the user to provide the movement required for proper printing. However, unlike in the case of a normal printer, the device doesn't require a predefined pattern of movement.

To print a document, the user would connect the printer to a computer or any other device that is capable of interfacing with a normal printer. Once the print command is given, the device indicates that it is ready to print.

The user moves the device to the corner of the page and then moves the device across the paper in any pattern. The part of the image that is to be printed at a particular position is calculated and printed when the device is brought over that position. Printing is tolerant to rotation of the device and will produce the correct results.

If any point is missed during the printing, the device indicates the direction where the missed spot is. If the device is accidentally lifted during printing, printing is paused and the user is asked to bring the device to the corner of the page before continuing. If the movement is too fast for reliable printing, the printing is paused and indication of over speed is given.

4. Design Overview

4.1 Device Components

The printer system composes a print document source (usually a computer), three optical sensors, inkjet print head, onboard processor.

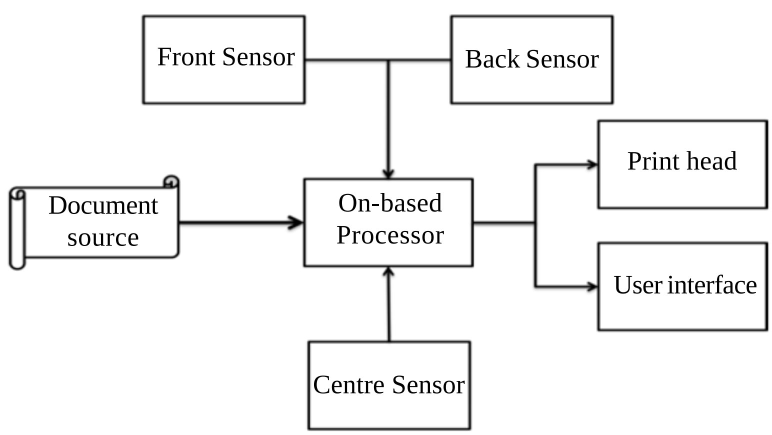

Figure 1. Device components

The document source can be any device that can issue a print command to a common printer. The On-board processor can be of two types

1) **A low power processor:** A low processing power processor like an ATmega8 can be used to control the print head and user interface. However, in this case, the processing such as image transformations have to be carried by the document source. The printing will be slower.

2) **A higher processor:** Any 16 bit processor can be used to accept the whole document and then apply transformations on board. This increases the operating speed and removes the need for specialised software to be installed.

The sensors are optical mouse sensors. We use Avago ADNS-2080 sensor.

The user interface is designed to be simple and intuitive and consists of 12 LEDs and a single push button.

For the print head, we chose the HP C6602A Black Cartridge along with HP Q2347A carriage. This particular model was chosen due to the easy availability of documentation regarding the timing sequences and interfacing properties.

4.2 Device Structure

The device consists of an enclosure measuring $110 \times 50 \times 70$ mm. The indicators and the button are placed on the top front end. The sensors and print head are placed inside the enclosure and works through openings provided on the base plate.

Figure 3. Bottom side of the assembled printer. The red patches are the red LED sources used in the sensors and the middle rectangular section is the print head opening

Figure 4. Cross section view

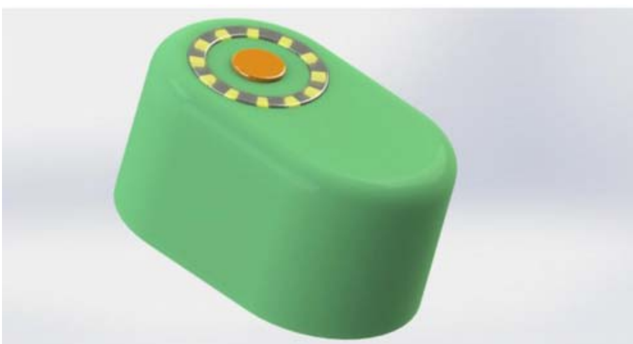

Figure 5. Isometric view

4.3 Sensors

The sensors used are ADNS 2080 from Avago. It provides reliable, accurate readings upto 2000 cpi resolution at upto 30 inches per second speed and 20g acceleration. The optical sensor along with the required optical arrangements is shown in Figure 6 [1].

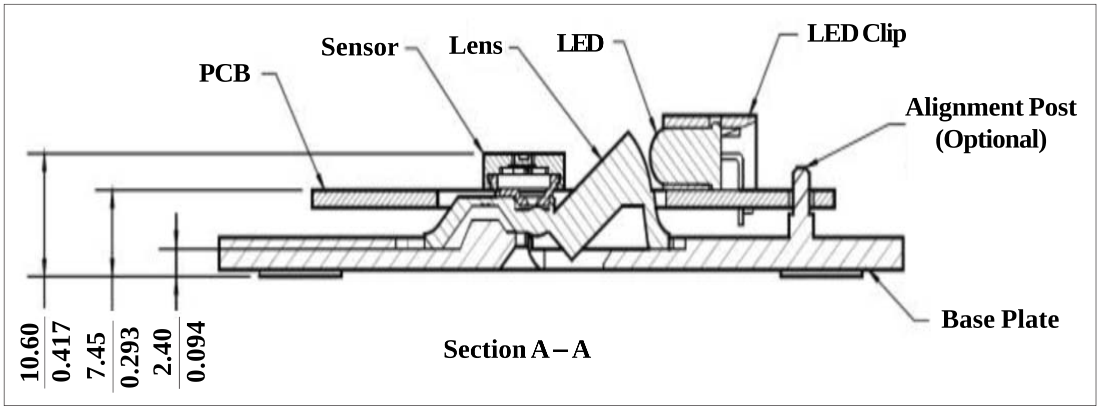

Figure 6. Sectional view of optical mouse sensor mounting components (optical mouse sensor, clip, lens, LED, PCB and base plate)

The sensors provide data via serial interface. The distance moved in the x and y directions along the plane since the last data read can be obtained from each sensor. This data acquisition is managed by the micro controller which polls the sensors depending upon the required update frequency.

4.4 Print system

The print head is a 96dpi system. The low resolution makes interfacing easy while still maintaining print qualities for simple text and graphics. The inkjet print head consists of 12 nozzles in a single line. The nozzles are fed through 65 Ω resistors. A small amount of ink is allowed to fill a chamber near the print head. A small resistor is located near the chamber. When a small pulse is sent through this resistor, it heats up, vaporising the ink. This gaseous ink then escapes, via a nozzle, condensing on the surface of the material being printed on. Another droplet of ink replaces the droplet that's just been fired, re-filling the printing chamber [2].

Reference [2] describes the different firing voltages and the corresponding pulse widths. We choose a 20V firing voltage with an optimum pulse width of 6.5 μs. To generate a 20V regulated voltage we are using a regulated boost convertor LM2577 to generate 20V from 5V input.

The nozzles require that a maximum of only 2 nozzles are fired simultaneously and that the firing should be of nozzles that are farthest apart. Furthermore, before the refiring of a nozzle, there should be a delay of 800 μs.

4.5 Interfacing

The system may be interfaced with the computer in two ways.

4.5.1 Wired

The wired technique is simpler to implement and cheaper. USB is the most preferable option.

4.5.2 Wireless

Wireless interface increases portability, introduces the ability to print from phones that do not support USB OTG. But is increases cost, complexity and battery consumption.

5. Processing

The inputs to the system are

1. dx_1 : displacement in x direction for 1st sensor

2. dy_1 : displacement in y direction for 1st sensor

3. dx_2 : displacement in x direction for 2nd sensor

4. dy_2 : displacement in y direction for 2nd sensor

5. CCD data from the 3rd sensor

6. Print Data input from computer

The system has to calculate the absolute rotation and position coordinates from this data. The algorithm used for this is explained in the following section. Once the position and angle are determined, the system processes the input to be printed. This includes verifying that the point was not printed previously, the current velocity is not too excessive for proper printing and that the printer is not lifted off the surface.

To ensure that points that are already printed are not reprinted, the software keeps track of the points that are printed and the ones that are left.

The initiating procedure includes finding a reference corner to fix the coordinate system. For this the user is directed to position the printer over the corner of the paper. Then the serial data is read to read the raw scanner data from the sensors. Then edge detection is applied to determine any detected edges. The orientation, motion are monitored to ensure proper detection with enough samples. The user input is also monitored to ensure that corners are not detected inadvertently.

The main processing required to print the image properly can be divided into 3 sections

1. Extract the displacement and orientation of the print head with respect to the global coordinates using the 2 sensor data.

2. Applying a transform to a section of the complete image to map/mask the image to the rotated print head nozzle positions.

3. Optimise the nozzle firing to account for the rotation effects caused by the slight asymmetry of the print nozzle. This process can be safely avoided as long as the printing angles are not too large.

5.1 Extraction

The distance moved by the print head given dx_1, dy_1, dx_2, dy_2 is

$$dx = \frac{dx_1 + dx_2}{2} \tag{1}$$

$$dy = \frac{dy_1 + dy_2}{2} \tag{2}$$

The rotation θ of the center of the print head is extracted as

$$\theta = 2\sin^{-1} \frac{d}{2L} \tag{3}$$

$$d = \sqrt{(dx_1 - dx_2)^2 + (dy_1 - dy_2)^2} \tag{4}$$

5.2 Transformation

Translation of (x, y) by a distance T_x, T_y can be expressed in the matrix form as

$$(x' \quad y' \quad 1) = (x \quad y \quad 1) \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ T_x & T_y & 1 \end{pmatrix} \tag{5}$$

$$x' = x + T_x \tag{6}$$

$$y' = y + T_y \tag{7}$$

Further, the rotation of a point (x, y) by α can be expressed as

$$(x' \quad y' \quad 1) = (x \quad y \quad 1)\begin{pmatrix} \cos\alpha & \sin\alpha & 0 \\ -\sin\alpha & \cos\alpha & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

$$x' = x\cos\alpha - y\sin\alpha \tag{8}$$

$$y' = y\cos\alpha + y\sin\alpha \tag{9}$$

To rotate a point about a pivot point, the pivot point is first brought to the origin using the above translation operation. Then all required points are rotated about the origin and then the pivot point is translated back to its initial position.

The part of the image to be printed is first extracted from the image. This is referred to as masking. The above transformation is applied to each point so that the effect is that of rotation of mask. This rotated mask uses line fitting algorithm to find the nearest pixel that should be printed for optimum pixel representation with minimum pixelations.

5.3 Error Correction

The sensors use successive dead reckoning which introduces the possibility of accumulating errors in displacement and rotation. To reduce this, the input image is first pre-processed by applying Prewitt edge detection algorithm to determine regions of interest with high number of identifiable edges.

During printing, the extracted image from sensor is also processed and edges detected. It is then compared to the pre-processed image and the known position and rotation to detect drift in the calculated values. The error is corrected and an error gradient is generated for further comparison. If any portion of the image lacks enough identifiable edges, an alternate algorithm is used where points are omitted during printing so that identifiable landmarks are obtained in otherwise uniform print. These landmarks will be printed-over near to the end of the print.

A third sensor as seen in figure is placed at the bottom of the device to aid in the function of error correction. The error accumulated is nullified by retrieving the image scanned by the third sensor and comparing it with the image section that should have been at that position according to the coordinates that the printing software thinks the device (or the sensor) is located at. The scanned image will be that belonging to coordinates that will be located at an offset from the coordinates calculated by the device. To get the values of this offset, cross correlation is applied between the two images. Usually when applying cross correlation to determine offset between two images a normalization function needs to be applied. But since both our input images are images that have undergone edge detection. They are essentially logic images, ie. either the pixel will be black (0) or white (1). In such a case the normalization function can be avoided. Cross correlation is applied in 2 dimensions (both x and y direction) and the output values are stored in a separate matrix.

The higher the value stored in the matrix, the higher the correlation between the 2 images. The location of the maximum value stored in the matrix will give the offset values between the 2 images. Simple addition/subtraction is done to indexes obtained from the matrix to convert the values to the coordinate system that is already being followed for the printing process. These offset values are added to the coordinates of the software to nullify the accumulated error. The error accumulating in the calculated angle of rotation also is nullified by extending the same process. It is carried out by applying correlation each time after rotating the scanned image by a small angle and storing each output for each angle in separate matrixes. Thus, we find to which matrix the maximum value of the maximum values from all matrixes belongs to. The angle of rotation corresponding to that matrix is the error angle and the corresponding x and y offsets are determined from the same matrix.

This error is determined at regular closely spaced intervals and the position is recalculated taking this into account.

For testing the algorithms and their robustness, we used an image with text. A smaller image is cropped out of it and blurred to different extents to simulate the blurred image extracted out of the third sensor. The different smaller images are extracted and the above comparison algorithm is applied. The calculated offset is compared with the introduced offset and the error factor is determined. This error is plotted for different values of blur. 2500 samples were tested for each blur level.

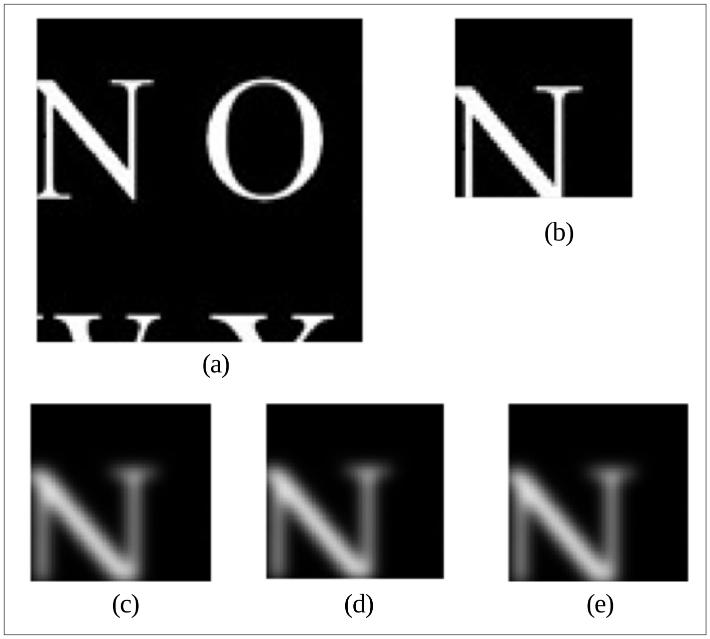

Figure 6. (a) Original image (b) sample cropped image (c) low blur (d) medium blur (e) high blur

It is observed that majority of the error values is centered at 0 ± 1. Some higher values were obtained when the number of features for reference is inadequate. In such cases, the alternate algorithm mentioned above is utilised. In the majority case, the results obtained were satisfactory for effective and judicious utilisation. Further, the techniques used in [3], [4], [6] and [7] maybe applied to further reduce error accumulation and increase efficiency.

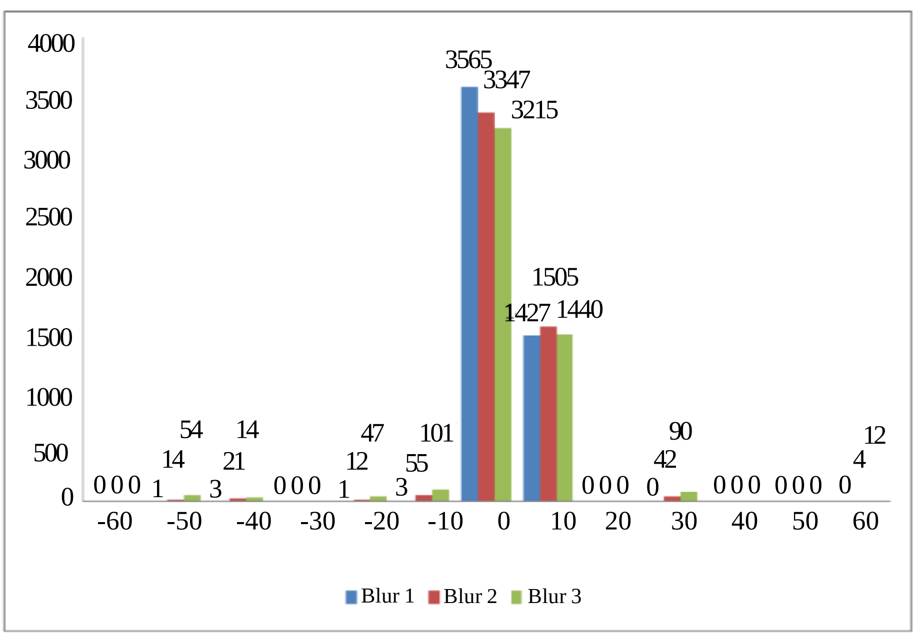

Figure 7. Frequency plot for offset errors corresponding to three different blur values

6. Conclusions

A printing system capable of printing on any surface is designed and its various possibilities are examined. Algorithms to detect the exact movement of the device along the surface, to detect possible error scenarios and to prevent error accumulation due to dead reckoning are implemented and simulated with good results. The device moves printing from the desktop to the pocket and is the first step in moving printing up to speed with other technology.

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